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An Assessment of the Eastern Scotian Shelf Shrimp Stock and Fishery in 2007 with an Outlook for 2008

Évaluation du stock et de la pêche en 2007 pour la crevette de l'est du plateau néo-écossais et perspectives pour 2008

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ABSTRACT

Stock biomass remains high - the 2007 DFO-industry survey index was the third highest of the 13 year series. Increases in Shrimp Fishing Areas (SFAs) 13, 15 and 17 offset a large decrease in SFA 14; however, the latter area continues to contain most of the biomass. The spawning stock biomass (females) remained high, as males from the large 2001 year class began to change sex. It is likely to remain high, as this year class continues to change sex during 2007-2008. It should support the higher Total Allowable Catch (5000mt) effected in 2005 through 2008. The 2002-2007 year classes are weaker, consequently, a biomass decrease is expected following the passage of the 2001 year class through the population, but the timing and rate of decrease will depend on the rate of sex change, recruitment to the fishable biomass and natural mortality of females. The population is concentrated in fewer length (and year) classes than previously, which may decrease population stability and increase vulnerability to exploitation. Commercial counts in 2007 were the highest on record due to the prominence and relatively small size of the 2001 year-class, which constituted the majority of the catch by numbers during 2006-2007 and by weight in 2007. Effort in SFA 14 remained high as fishers continued to take advantage of good catch rates and accumulated biomass in this area. The proportion of the catch taken during the ovigerous period remained relatively low in 2007, with most of the effort occuring during the summer months. The percentage of females in the catch remained relatively low due to the large numbers of shrimp from the 2001 year class, which have delayed sex change, presumably due to their slower growth rate. Total and female exploitation remained below average; however, exploitation of the smallest shrimp (<19mm CL [carapace length]) increased substantially in 2007, apparently due to low recent recruitment and sustained effort. Exploitation of the largest >26mm shrimp also increased. Commercial catch rates remained high in 2007, and spatial indicators show that the area with the highest commercial catch rates remains large.

RÉSUMÉ

La biomasse du stock demeure élevée – l'indice du relevé de 2007 du MPO et de l'industrie est le troisième le plus élevé de la série de 13 ans. Les augmentations enregistrées dans les zones de pêche à la crevette (ZPC) 13, 15 et 17 ont compensé pour la forte diminution observée dans la ZPC 14; cependant, cette dernière zone contient toujours la majeure partie de la biomasse. La biomasse du stock reproducteur (femelles) est demeurée élevée, car les mâles de l'importante classe d'âge de 2001 ont commencé leur mutation sexuelle. Cette biomasse devrait demeurer élevée, car cette classe d'âge continue sa mutation sexuelle en 2007-2008. Elle devrait soutenir le total autorisé des captures plus élevé (5000 tm) établi de 2005 à 2008. Les classes d'âge de 2002-2007 sont moins abondantes et, par conséquent, une diminution de la biomasse est prévue après le passage de la classe d'âge de 2001 dans la population, mais le moment où surviendra cette diminution et le taux de diminution seront fonction du taux de mutation sexuelle, du recrutement à la biomasse exploitable et de la mortalité naturelle chez les femelles. La population est concentrée dans moins de catégories de longueurs (et de classes d'âges) que précédemment, ce qui peut réduire la stabilité de la population et augmenter sa vulnérabilité à la pêche. Les dénombrements dans les pêches commerciales en 2007 ont les plus élevés jamais enregistrés en raison de la prépondérance et de la taille relativement petite de la classe d'âge de 2001, qui a constitué la majorité des prises en nombre en 2006-2007 et en poids en 2007. L'effort dans la ZPC 14 est demeuré important alors que les pêcheurs ont continué à profiter de bons taux de prise et de la biomasse accumulée dans ce secteur. La proportion des prises enregistrées pendant la période ovigère est demeurée relativement faible en 2007, la majeure partie de l'effort ayant été consenti pendant les mois d'été. Le pourcentage de femelles dans les prises est demeuré relativement faible en raison du grand nombre de crevettes de la classe d'âge de 2001, qui ont vraisemblablement retardé leur mutation sexuelle en raison de leur taux de croissance plus lent. Les prises totales et les prises chez les femelles sont demeurées inférieures à la moyenne; cependant, les prises chez les crevettes de plus petite taille (LC < 19 mm [longueur de carapace]) ont augmenté sensiblement en 2007, apparemment en raison du faible recrutement observé récemment et de l'effort soutenu. Les prises chez les plus grandes crevettes (> 26 mm) ont également augmenté. Le taux de prise de la pêche commerciale est demeuré élevé en 2007, et les indicateurs spatiaux démontrent que la zone affichant les taux de prise par la pêche commerciale les plus élevés demeure vaste.

INTRODUCTION

The biology of northern shrimp, *Pandalus borealis*, is reviewed in Shumway et al. (1985) for various stocks world-wide, and by Koeller (1996a, 2000, 2006) and Koeller et al. (2000a, 2003) for the eastern Scotian Shelf stock. The rationale for the assessment and management approach used is described in Koeller et al. (2000b). The history of the eastern Scotian Shelf shrimp fishery and recent stock assessments are given in Koeller et al. (1996b, 1996d, 1997, 1998, 1999, 2001, 2002, 2003b, 2004, 2005, 2006a, 2006b). Although there has been some shrimp fishing on the Scotian Shelf since the 1960s, the Nova Scotia fishery began to expand toward its full potential only when groundfish bycatch restrictions were overcome with the introduction of the Nordmore grate in 1991. The Total Allowable Catch (TAC) was first reached in 1994 when individual Shrimp Fishing Area (SFAs) quotas were removed. With biomass at historical highs and continued good recruitment, the TAC was raised from 3100mt to 3600mt for 1997 and to 3800mt for 1998. Despite evidence of reduced recruitment to the population, and because of continued high spawning stock biomasses and large year classes (1993-1995) recruiting to the fishery, the TAC was increased to 5000mt for 1999 and to 5500mt for 2000. With the strong year classes completing their life cycle; recruitment only average; a decreasing trend in the survey biomass; increasing exploitation rates; changes in the distribution of the resource, possibly due to increasing temperatures and\or size separation; and increasing harvest levels during the ovigerous period, the TAC was reduced to 5000 mt for 2001 and to 3000 mt for 2002 and 2003. In 2003, the survey index increased for the first time following three successive declines and the TAC was raised to 3500mt for 2004. Signs of improved recruitment in the form of a very strong 2001 year class suggested that the stock would continue to increase. The 2004 survey biomass was the highest on record and the TAC was raised to 5000mt for the 2005 fishery. Despite continuing good catch rates, the TAC was not caught in 2005 and 2006 for a number of reasons, including poor market conditions, bad weather, soft shrimp, gear conflicts (snow crab fishery) and other logistic problems, but these were largely overcome in 2007 when ~90% of the TAC was caught.

In 2001 shrimp prices dropped sharply, partly due to large quantities of small shrimp in the Newfoundland and Labrador inshore fishery. This resulted in voluntary closures or greatly reduced fishing effort in the Newfoundland, Gulf of St. Lawrence and eastern Scotian Shelf fisheries during the summer. There were no closures on the Scotian Shelf in 2002. In 2003-2007 effort on the Scotian Shelf virtually stopped during the summer to avoid soft shrimp and crab traps but picked up again during the fall. Prices for coldwater shrimp have remained low in recent years due to high inventories, small shrimp, and competition from warm water wild and aquacultured shrimp production. This has had serious and widespread economic consequences for the coldwater shrimp industry, ranging from the large offshore concerns (freezer trawlers) operating on both sides of the North Atlantic, to the small inshore trap fishery in Chedabucto Bay, Nova Scotia, which had very low effort during 2005-2007.

Since 1999 many shrimp stock assessments have included a "traffic light" analysis (Koeller et al. 2000b, Mohn et al. 2001, Halliday et al. 2001, Caddy et al. 2005). The organisation of this report is based on this multiple indicator diagnostic approach, with the "Methods" and "Results and Discussion" sections for individual indicators grouped under headings representing "characteristics", in the order they are presented in the summary. The sections on each indicator in "Methods" provide the methods used to calculate the indicators, and describe their relevance to the characteristic they represent. In "Results and Discussion," the indicators always represent summary data for the entire area, i.e., all SFAs combined, according to the current practice of managing the fishery as one stock. The indicator series used in the analysis is given as an uncaptioned figure directly after the indicator heading. In addition to the indicator time series themselves, their sections in "Results and Discussion" include data which support

trends seen in the summarized data. These data are given as numbered and captioned figures and tables at the end of the document. For example, individual SFA data often replicate the indicator trends and thus substantiate them. Supporting data may be entirely different from the main indicator, for example: catch rates in the shrimp trap fishery supported the apparent increasing shrimp aggregation shown by the survey and Catch Per Unit Effort (CPUE) data; anecdotal reports of large numbers of 1-year old shrimp found on Cape Breton beaches in 2002 supported survey data indicating a strong 2001 year class, etc. This additional information may be used in the interpretation associated with any change that is given in the "Results and Discussion," but it is not used in the summary traffic light 'scores'. In any case, it should be noted that such scoring is not at this point intended to be translated directly into management action, for example, in the form of rules linked to summary scores. The "traffic light" is currently seen simply as a tool for displaying, summarising and synthesizing a large number of relevant yet disparate data sources into a consensus opinion on the health of the stock. More formal "reference points" and "control rules" within the framework of the traffic light analysis will be developed during the next 2 years in order to meet conditions associated with the development if the Integrated Fisheries Management Plan.

The shrimp fishing areas on the Scotian Shelf are shown in Figure 1. Table 1 provides basic catch statistics for the fishery since 1980 and Table 2 gives licensing information for the recent period covered under sharing agreements between the Scotia Fundy and Gulf fleets and a multi-year (1998-2002) Integrated Management Plan that included provisions for temporary licences during favourable periods. Although this management plan expired in 2002 and negotiations for a renewed agreement were not successful, the 2003-2006 fisheries essentially operated under its provisions, which included removal of temporary licences when the quota dropped below an agreed threshold. Disagreement between temporary licence holders, who wanted permanency, and the permanent fleet component prevented the successful negotiation of a new multi-year plan. This stumbling block was removed when temporary licences were made permanent, albeit with a lower ITQ than previous permanent licence holders, for the 2005 fishery and it currently operates under an Integrated Fisheries Management Plan for 2007-2011.

The experimental trap fishery was not under quota management from 1995-1998 except for a 500 mt precautionary 'cap', and so the total catch exceeded the TAC due to the trap fishery catch. When the trap fishery in Chedebucto Bay was made permanent in 1999 a trap quota was set at 10% of the total TAC, e.g., 500 tons of the 5000 mt TAC was initially allocated to trappers in 1999. Most of any uncaught portion of the initial trap quota was reallocated to the mobile fleet. This reallocation has tended to be late in the year and some fishers were unable to take advantage of the additional quota, hence the overall catch has been lower than the TAC since 1999, although other factors have contributed to this as noted above. Note also that the trap quota reallocation has been based on projected catches that were not achieved during some years. In an attempt to avoid reallocations, in 2004 only 300mt were allocated to this fishery which is closer to its capacity. With an increase in the TAC for 2005 this was increased to 392mt, but trap fishing effort and catch were very low during 2005-2007 due to poor market conditions.

METHODS AND MATERIALS

Traffic Light Indicators

Default boundaries between traffic lights for individual indicators, i.e., transition from green to yellow and from yellow to red were arbitrarily taken as the 0.66 and 0.33 percentiles, respectively, of the data in the series unless an increase was considered bad for stock health, in

which case these were reversed. Note that for commercial catch per unit effort series the "polarity" of the default boundary should be considered with other indicators for certain years. Clearly, the increase in the two commercial CPUE series, coupled with increased aggregation and decreased survey abundance, indicated that the increase in the two commercial CPUE series in the most recent years should be viewed as a negative development. However, traffic lights were not changed from the default in this document. Similarly, the record high counts experienced by fishers in 2005 are negative in the context of the fishing impact characteristic because they are indicative of growth overfishing, but if considered within the production characteristic they are positive because they substantiate fishery independent (survey) results of exceptional 4-year old shrimp abundance.

ABUNDANCE

Research Vessel Abundance Index

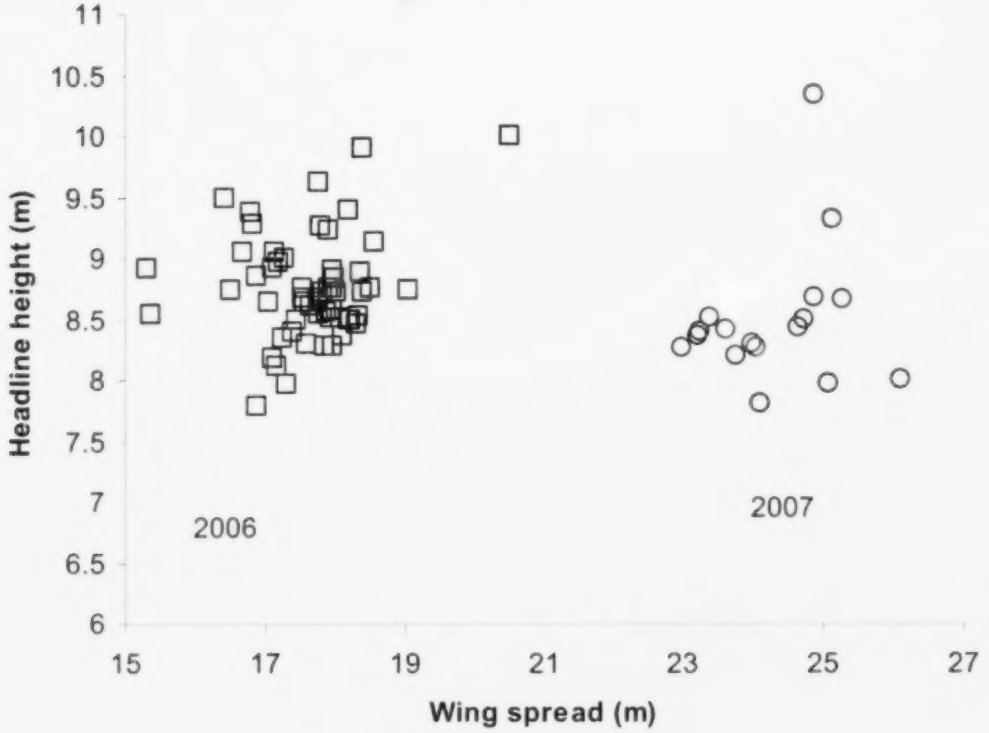
A thirteenth industry-funded trawl survey, incorporating a mixed stratified random - fixed station design, was conducted in June 2007. Survey design and station selection methods were similar to previous surveys completed in 1995-2006: fishing depths >100 fathoms, randomly selected stations in strata 13 and 15; fixed stations in strata 14 due to the difficulty in finding trawlable bottom; 30 minute tow length; and 2.5 knot vessel speed. Stations in Strata 17 (inshore) were selected randomly at all depths having a bottom type identified as La Have clay on Atlantic Geosciences Centre surficial geology maps. The 2007 survey was again completed by MV *All Seven* (sixth year for this vessel/crew) fishing the standard survey trawl (Gourock #1126 2-bridle shrimp trawl and #9 Bison doors). Catches were standardised to the target distance travelled at 2.5 knots for 30 min (1.25 nm). Biomass/population estimates and bootstrapped confidence intervals (Smith 1997) were calculated using the product of the average measured wing spread (17.4 m) of the survey trawl and the distance travelled during a standard survey set (1.25nm) as the standard unit area swept by each set (Halliday and Koeller 1981).

The co-operative DFO-industry series begun in 1995 used several different vessel-trawl combinations requiring comparative fishing experiments in 1996 and 1997 (Koeller et al. 1997). In order to obtain a wider range of indicator values for this series it was extended to include DFO surveys conducted in 1982-88, a period of low abundance in contrast to the present period of high abundance. There were no comparative fishing experiments that allowed direct intercalibration of the two survey series, consequently catch data were only adjusted by the difference in the wing spreads of the trawls used. Wing spreads were based on the performance specifications of the trawl used for the earlier series, and from actual measurements for the latter series. However, it is probable that the trawl used during the recent series was more efficient in catching shrimp than during the 1982-88 series. Consequently the large differences in catch rates between the two series may be exaggerated and should be interpreted cautiously. Since the cod end mesh size in both series was the same (40 mm) size selectivities of the two series were assumed to be the same.

NETMINDER Sensor Problems During the 2007 Survey

Measurements of trawl wing spread and headline height were made during all surveys; however, the vessel's NETMINDER wing spread sensors used in previous surveys were not available for the 2007 survey, so identical NETMINDER sensors were borrowed from the DFO snow crab program. These were attached in the usual manner and the software configured as previously. Wingspread readings were normal and within the variability of previous surveys for the first three sets (17.6-18.3m) but then changed abruptly to average consistently higher

(24.3m) than in previous years (17.2m) for the duration of the survey. This significant change (35%) in wing spread should have affected overall trawl geometry and efficiency; however, other trawl measurements appeared to be unaffected. Successful wing spread measurements were within the variability of previous surveys as shown in the figure below, with a similar average from the previous year (8.64m in 2007 versus 8.75m in 2006).



Since the circumference of the trawl opening is constant, such a large increase in wing spread, i.e., horizontal measurement of net mouth opening, should have been accompanied by a proportional decrease in headline height, i.e., vertical mouth opening as is usually observed, but this was not the case. Inspections prior to the survey on the wharf including direct measurements of headline and footrope lengths, confirmed that the net met specifications and that everything was rigged as in previous years (same floats, doors, bridles and attachment points, etc.). Gear inspection during the survey also indicated that the trawl was fishing properly (door performance from door shine, bottom contact from bycatch, trawl spread from warp angles). Discussion with NETMINDER technicians indicated that inappropriate software configurations, particularly signal time delays, could result in erroneous but consistent readings. However, no change was observed after checking and configuring the software with the slightly different settings used on both shrimp and crab surveys in the past. Sensor misalignment on the wings was not the source of the problem since these were attached as previously and appeared to be well aligned when observed at the surface. It was also probably not due to sensor transmissions since use of the same sensors after the shrimp survey by the snow crab group found no change in their gear, which performed as expected. Since there was no change in headline height after the increase in wing spread readings following the third set, it is likely that the wing spread readings were erroneous. Possibly an internal (non configurational) software or hardware problem on the vessel's NETMINDER receiver may have been responsible, but this has not yet been confirmed. It should be noted that an almost identical situation occurred during

the 2004 survey (Koeller et al. 2005). At that time the *headline* showed a large (30%) increase to 8.5m from the average of previous surveys of 6.5 m, without a corresponding decrease in wingspread. At the time this was attributed to a new trawl (but with original specifications) and/or faulty sensor attachment (Koeller et al. 2005), but the high readings have persisted in subsequent surveys despite adjustments, and the two problems may be related.

This is an important issue since the application of the usual swept area formula and set by set adjustments of catches to a standard unit based on distance travelled and wingspread would have resulted in a approximately 35% decrease in the biomass estimate. It should be noted that even if a large "spontaneous" increase in wing spread had actually occurred, it is unlikely that efficiency is linearly related to wing spread at such large deviations from normal trawl geometry. However, a possible problem with the net and survey results during the 2007 survey cannot be ruled out and should be included when considering sources of uncertainty in the assessment.

***Note – *Subsequent inspection found significant fouling on the hull-mounted microphone, which was then cleaned. The same sensors produced normal readings for both headline and wing spread during the 2008 survey.*

Gulf Vessels Catch Per Unit Effort

A CPUE index for Gulf based vessels, which have the longest history in the fishery, is calculated as a simple unstandardised mean catch/hour fished for all vessels fishing in any given year. These are the largest vessels in the fleet and although the participating vessels (and fishing gear) have changed considerably, they have always been >65 ft in length, compared to the <65ft Nova Scotia fleet. This is an important time series because it spans periods of both high and low abundance of the stock. However, since fishing methods and gear have probably improved over the years, it is likely that the differences in CPUEs between the period of low abundance (pre-1993) and the recent high abundances are exaggerated and should be interpreted cautiously.

Commercial Trawler Standardized Catch Per Unit Effort

The standardised CPUE series for 1993-2007 uses data from April-July inclusive, the months when the bulk of the TAC is caught, for 17 vessels that have fished for at least 7 of the 11 year series. A multiple regression analysis was conducted with year, month, area and vessel as categorical components. Predicted values and confidence limits for a reference vessel, month and area were then calculated for each year according to Gavaris (1980). Data on catch rates were obtained from fishers' logs required from all participants and provided by DFO Maritimes Region Statistics Branch.

An increase in this and the preceding indicator does not necessarily indicate increasing stock abundance, especially when coupled with a decrease in the area fished (see commercial fishing area below) or a decrease in the dispersion of the stock (see research vessel coefficient of variation below).

Research Vessel (RV) Coefficient of Variation

A measure of dispersion was calculated from survey data as the simple coefficient of variation of all survey sets for each year, i.e., the standard deviation of all catches divided by the overall average weight caught. An increase in this statistic indicates increased aggregation of shrimp on the grounds.

Commercial Fishing Area

A measure of dispersion was also calculated from commercial data as the number of area units (1 minute squares) having an average catch of >250kg per hour. With catch rates continuing to increase but survey estimates decreasing, a decrease in this index would indicate a concentration of the remaining stock in smaller areas. Interpretations of changes in this index should also take into account changes in the area of other average catch rate categories (see Figure 5), indices of abundance, and the spatial distribution of effort.

PRODUCTION

RV Age 1 Abundance

The Age 2 abundance indicator discussed below is currently the only estimate of recruitment to the population with a longer (since 1995) time series. However, these shrimp are not caught efficiently by the standard survey trawl (since 2002). This is being addressed by a small meshed "belly-bag" attached on the footrope under the belly of the standard survey trawl during all regular June survey sets. Only 6 years of data are now available; however, this gear correctly identified the 2001 year class as large one year before it recruited to the survey trawl, and it appears to be useful in assessing year class strength 4-5 years before recruitment to the fishery. Results from the belly bag are currently not included in the traffic light analysis, but are considered as supporting evidence for other recruitment indicators (e.g., Figure 10). It may be included as the length of the series increases and the value of the data is established. Belly bag catches of *P. borealis* were frozen and returned to the laboratory for analysis. In most cases the entire catch was processed, but the largest catches were subsampled.

RV Age 2 Abundance

A random sample of 8 pounds of shrimp (approximately 300 individuals) was collected from the catch of each survey set and frozen for detailed analysis, i.e., carapace length, individual weight, sex and egg developmental stage. Survey population estimates (numbers) were determined by the swept area method using individual set length frequencies and weights caught, and a length-weight relationship. Survey population estimates by age group were then estimated by separating total population at length estimates from the swept area method into inferred age groups using modal analysis (MIX, MacDonald and Pitcher 1979).

RV Age 4 Abundance

Age 4 abundance is calculated as per Age 2 above, from survey population at length estimates (swept area) and modal analysis.

On the Scotian Shelf most Age 4 shrimp are in their final year as males. This group represents shrimp that will breed as males during the survey year and will change sex the following year. Since females comprise most of the catch, the last-year males are a measure of recruitment to the fishery.

RV Spawning Stock Biomass (Females)

The spawning stock biomass (SSB), or total weight of females in the population, was calculated with the swept area method from the weight of females in each set, determined by identifying females and their lengths in the detailed sample, the total catch weight, and a length weight

relationship. This estimate includes shrimp that were in the transitional stage during the survey. On the Scotian Shelf transitional shrimp are seldom found during the fall, i.e., all transitionals complete sex change during the summer and extrude eggs during the late summer.

A clear stock-recruitment relationship has not been identified for the Scotian Shelf (Figure 16), although it has been for some other pandalid stocks, e.g., the Gulf of Maine, California-Oregon. On the Scotian Shelf a large population increase began during the late 1980s when SSBs were about 4,300mt, about 30% of those found in the late 1990s. It would therefore be prudent not to let the SSB decrease below 4,300; however, the stock increase at these SSB levels occurred at specific favourable environmental conditions (cold water temperatures and decreasing natural mortality due to predation) and negligible fishing mortalities. Consequently, this SSB should be considered as the very lowest the stock should be allowed to decline. Coincidently, this is nearly identical to the default 0.33 percentile used as the red limit for all indicators, including SSB.

SSB by itself is not a measure of reproductive capacity. Since fecundity is directly related to size, it should be considered in conjunction with the average size at sex transition, maximum size and amount of fishing during the ovigerous period. In addition, multiparous females tend not to spawn every year. An index of egg production is under development.

Size at Sex Transition (L_t)

Shrimp in transition from the male to the female are identified by the pleopod development method and their average size is calculated as overall weighted average from all sets in the survey.

Koeller et al. (2003b) and Koeller (2006) show that size at transition is related to growth rate. It is hypothesised that an increase in growth rate, due to density dependant effects or temperature increases (Koeller et al. 2000a), results in decreases in the size at transition, maximum size and fecundity, followed by a population decline.

Maximum Size (L_{max})

Average annual maximum size is calculated as the average of the sample maximum sizes.

The ratio of size at sex transition to maximum size was hypothesized to be constant (invariant) at about 0.8-0.9 for all stocks of *P. borealis* (Charnov and Skulladotir 2000). This rule was shown to apply to the Scotian Shelf (Koeller et al. 2003b, Koeller 2006). Consequently, maximum size attained in the population is another growth indicator i.e. change in maximum size is probably indicative of a change in growth rate. The relationship between L_t or L_{max} to changes in growth rate is complex due to the influence of other factors including concurrent changes in longevity and natural mortality (e.g. slower growing shrimp tend to live longer).

Predation

A predation index is calculated as the mean catch/set of all major groundfish species (codes<1000) combined from the summer groundfish survey for strata which encompass the shrimp holes i.e. Strata 443-445 and 459.

This is considered an index of natural mortality. Groundfish abundance is negatively correlated with shrimp abundance on the Scotian Shelf and in most other shrimp fishing areas.

FISHING EFFECTS

Commercial Counts

Fishers determine the number of shrimp per pound (the "count") in their catches soon after they are brought aboard in order to determine the price which they will obtain from buyers and adjust fishing practices (especially location) accordingly. This information is of economic importance and is often conveyed to other fishers or buyers before landing, so care is usually taken in obtaining and recording it. The methodology used is basic (number of shrimp in a fixed volume, often a tobacco can, that weighs about 1 pound) but generally agrees with more rigorous methods used by buyers. The index used here is the simple arithmetic average of all counts reported in log books for the year.

This indicator is a measure of the ease or difficulty fishers are having in "making the count," i.e., getting the best price for their shrimp. An increase in the count could indicate that a) recruitment is good and there are so many small shrimp it is difficult to avoid them or b) the population of larger shrimp is declining, or a combination of a) and b). Moreover, an increase in this indicator can be considered good (increased recruitment) or bad (growth overfishing) depending on whether it is placed in the production or fishing effects characteristic. Consequently, this indicator must be considered with others including abundance indices of the different age categories. Note that counts also change considerably during the fishing season, usually starting relatively high, decreasing to a minimum in July, and increasing thereafter, probably due to size specific changes in vertical and\or geographic distribution associated with changes in day length.

Total Exploitation Index

An overall index of exploitation rate is calculated as the total catch weight divided by the RV biomass estimated using the swept area method.

The RV biomass estimate has been shown to be underestimated by as much as 25% because of lack of coverage in shallow areas surrounding the shrimp holes; consequently the exploitation rate is probably overestimated. This indicator is therefore considered an index of exploitation. Since the survey uses a common commercial trawl with a Nordmore grid, its selectivity is similar to commercial gear. The biomass used to estimate exploitation can be considered an estimate of "fishable biomass."

Female Exploitation Index

This is calculated as the estimated weight of females in the catch divided by the weight of females in the population from the survey, i.e., the spawning stock biomass. An industry-funded port sampling program that began in 1995 allows determination of the catch composition by developmental stage and size from detailed analyses as per survey samples. Samples were collected during the fishery in all areas from all fleet components including vessels <65' length over all (LOA) landing mainly in Canso and vessels >65' LOA landing mainly in Arichat. The number of samples per month and area was approximately allocated in proportion to weight caught. Catch at length was determined from a weighted length frequency and a length-weight relationship.

Female exploitation is of interest because the shrimp fishery is selective for the larger females. It can be considered one measure of the impact of fishing on the reproductive potential of the stock.

Proportion of Females in Catch

The proportion of females in the catch by weight to the total catch weight is calculated from commercial samples which identify females, lengths and individual weights as per survey samples.

A decrease in this indicator could indicate a decrease in the number of larger shrimp in the population due to fishing removals and an increased reliance on smaller animals, i.e., possible growth overfishing and/or recruitment overfishing. It should be interpreted cautiously and in combination with other indicators, since it could also indicate good recruitment conditions and difficulty in avoiding young shrimp.

Average Size of Females in Catch

This indicator is calculated as the overall annual average size of females from port samples collected throughout the fishery.

A decrease in this indicator could indicate a decrease in the number of larger shrimp in the population due to fishing removals and an increased reliance on smaller animals, i.e., possible growth overfishing and/or recruitment overfishing.

Fishing During Ovigerous Period

This is calculated as the percent of the total catch caught during August-March, the usual period when females are carrying eggs.

Since most eggs are laid by a single age class (i.e., age 5) enough females must escape the fishery to prevent recruitment overfishing. The fishery has generally concentrated in the non-ovigerous period with most of the catch taken during May-July; however, as TACs increased an increasing amount of the catch has been taken during the ovigerous period. This indicator should be included with spawning stock biomass and size at transition when considering the population's overall reproductive capacity, since their negative effects are probably cumulative. For example, the minimum SSB of 4,300 mentioned above would be considerably less in terms of effective reproductive capacity if most is taken before egg hatching.

ECOSYSTEM

Population Age-length Evenness

This indicator is based on the assumption that a population spread evenly across length or age classes is more resilient to environmental or fishing perturbations than one where the population is concentrated in fewer length or age classes. It is calculated from the survey population-at-length estimate as Shannon's equitability index, E_H, which is obtained from Shannon's diversity index, H. The latter is calculated from the proportion (p) of the population in each of the total number of length groups (S).

$$H = -\sum_{i=1}^{S} p_i \ln p_i$$

This indicator is placed under the ecosystem characteristic assuming that evenness is related to the population's robustness or resiliency to various perturbations within the ecosystem, but it could also have been placed under fishing effects, since fishing will remove the largest/oldest length/age classes, or production, since an even length/age distribution implies stable recruitment. On the other hand, this index will also respond to the passage of an exceptional year class through the population, which may not be a negative development if the abundance of other year classes remains relatively stable.

RV Bottom Temperatures

This index is calculated from July groundfish survey data as the mean bottom temperatures at depths >100m in sampling strata (443, 444, 445 and 459) on the Eastern Scotian Shelf that encompass the shrimp grounds. Initially, bottom temperatures on these surveys were determined with expendable bathythermographs or reversing thermometers, but more recently (since 1995) they were obtained from Seabird CTD profiles. Shrimp survey bottom temperatures are determined throughout each shrimp survey set with a continuous temperature recorder (Vemco Ltd.) attached to the headline of the trawl. Trends in these data generally agree with groundfish survey data; however, the latter is used in the analysis because of the longer time series.

It is hypothesized that warmer water temperatures have a negative influence on shrimp populations because of the decreased fecundity associated with increased growth rates, decreased size at transition, and decreased maximum size as described above. Recent work also indicates that colder bottom temperatures increase egg incubation times resulting in later hatching times, which are closer to favourable spring growing conditions (warmer surface water and the spring phytoplankton bloom).

July Sea Surface Temperatures

Sea surface temperatures (SSTs) are calculated as average temperatures within defined rectangles encompassing the shrimp holes, using the Oceans Sciences and Biological Oceanography Section SST databases.

Negative correlations between SSTs and lagged population estimates are common for the southern *P. borealis* stocks, including the Scotian Shelf. This may be related to water-column stability and the match-mismatch of resulting phytoplankton bloom conditions with hatching times as hypothesised by Ouellet et al. (2007). According to their results, this indicator should be changed to represent SSTs at hatching time (to be updated for next year's assessment).

RV Capelin Abundance

This is calculated as the average catch/tow in numbers from the July groundfish survey in strata 443-445 and 459.

Capelin are among the most common bycatch species both in the Scotian Shelf shrimp fishery and the June shrimp survey. Here they have been shown to increase in abundance during cold periods which are also favourable to shrimp, and so can be considered a sympatric species (e.g., Frank et al. 1994). Their presence can therefore be considered an indicator of conditions favourable to the production of shrimp.

RV Cod Recruitment

This is calculated as the average number of <30cm fish/tow from the July groundfish survey in strata 443-445 and 459.

Cod abundance is generally negatively correlated with shrimp abundance for most North Atlantic stocks, including the Scotian Shelf. This is probably partly due to large scale environmental influences such as temperature that appear to have opposite effects on cod and shrimp population dynamics, as well as a trophic effect of cod predation on shrimp. Restricting this indicator to juvenile cod may therefore decrease the influence of predation and have some predictive value for shrimp abundance.

RV Greenland Halibut Recruitment

This is calculated as the average number of <30cm fish/tow from the July groundfish survey in strata 443-445 and 459.

Greenland halibut is a cold water species whose abundance is often positively correlated to shrimp abundance. However, it should be noted that Greenland halibut are also known predators of shrimp, and so an increase in this indicator is both positive and negative. Restricting this indicator to juvenile halibut may decrease the influence of predation and have some predictive value for shrimp abundance.

RV Snow Crab Recruitment

This is the stratified random abundance index for pre-recruits calculated for the snow crab assessment from annual crab surveys in southeastern Nova Scotia. Like Greenland halibut and capelin, snow crab is a cold water species that is often positively correlated with shrimp abundance.

Traffic Light Summary

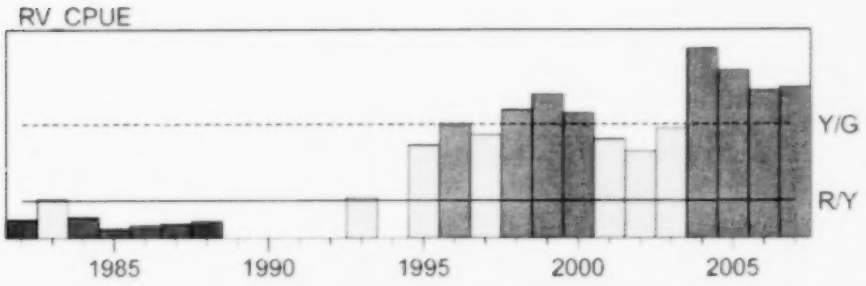
Individual traffic light indicators were summarised using simple averaging. Each indicator is given a value according to its colour, i.e., green = 3, yellow = 2 and red = 1, and an average is calculated. This average is assigned a "summary colour" according to limits determined by the probability distribution of possible outcomes, i.e., the limits between red, yellow and green are set so that each of the three summary colours has an equal probability of being assigned in a random set of individual indicator colours/values. The Regional Advisory Process (RAP) review committee has emphasised that the summary is difficult to interpret and should not be the primary consideration in the advice, because issues such as weighting of indicators and harvest rules associated with any particular summary have not been resolved.

RESULTS AND DISCUSSION

Input data for the traffic light analysis are given in Table 3. These data are graphed in the uncaptioned figures immediately following the indicator headings in the section below.

ABUNDANCE

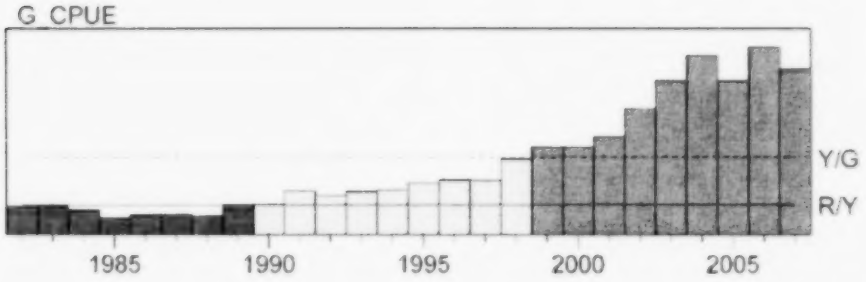
Research Vessel Abundance Index



The stratified survey estimate for 2007 (representing a biomass of 38,431mt using the swept area method) increased slightly from the previous year and is the third highest of the series. (Figure 2, Table 4, 6). A large decrease in Stratum 14 was offset by increases in the other areas. This stratum continues to contain the highest biomass of all areas. The decrease in Stratum 14 may be related to increased fishing pressure as fisheries took advantage of the high abundance in this area, resulting in relatively high exploitation rate here (~15%, Table 6). The distribution of survey catches during the last 2 years is shown in Figure 6.

Interpretation: Despite decreases since the record biomass of 2004, overall stock biomass remains high. Abundance changes within SFAs may partially reflect changing fishing patterns and exploitation rates.

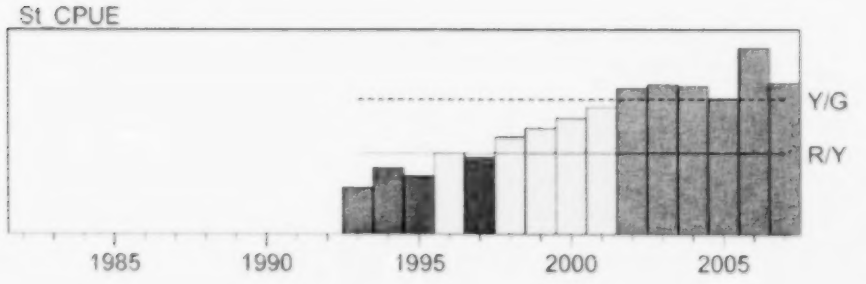
Gulf Vessels Catch Per Unit Effort



The unstandardised Gulf Vessel CPUE has shown an increasing trend since the 1980s and has fluctuated at a high level since 2003.

Interpretation: Catch rates by Gulf vessels continue to be excellent and there is no indication of a downturn.

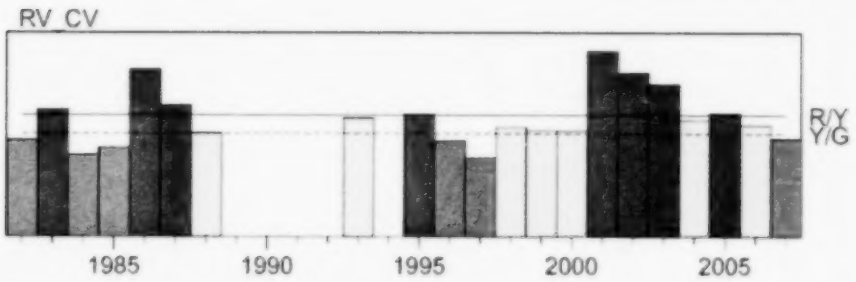
Commercial Trawler Standardized Catch Per Unit Effort



The standardized CPUE series followed a similar pattern to the Gulf series, showing an increasing trend during most of the series, with fluctuations at a high level since 2002. Although survey and cpue indices currently both indicate high abundance (Figure 3A) these have diverged in the past. Spatial analyses (see below) have previously shown that CPUEs are not always representative of abundance, but can be influenced by fleet reactions to changes in distribution and densities of shrimp concentrations associated with strong year classes. The spatial distribution of effort during the last two years is shown in Figure 7 and the seasonal (monthly) distribution of catch, effort and CPUEs in Figure 8. These did not change greatly in 2007 from previous years.

Interpretation: Catch rates continue to be excellent for all fleet sectors due to continued high abundances.

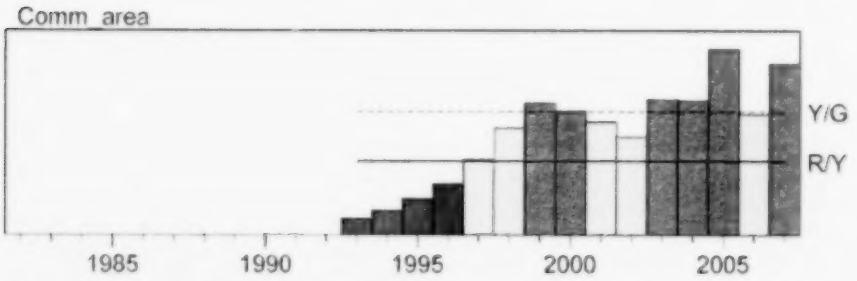
Research Vessel Coefficient of Variation



The survey measure of dispersion (overall CV) decreased again in 2007, and there has been a decreasing trend since 2001 (Figure 4, 6).

Interpretation: The relative stability of this indicator at a low value during the last few years appears to be associated with the currently high and evenly distributed abundance, mainly of the 2001 year class.

Commercial Fishing Area



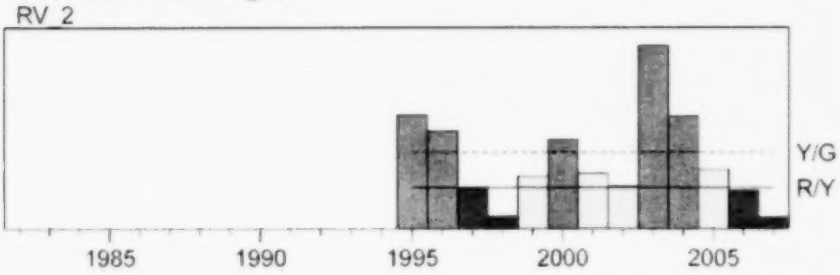
This indicator (area with commercial catch rates >250kg/hour) must be considered with the areas of other catch rates in order to interpret changing distribution and dispersion patterns of the resource. The >250kg/hour area increased since the beginning of the series until 1999, when it began to decrease because shrimp from several strong year classes formed dense concentrations in a smaller area during the biomass decrease. Consistent with this interpretation, the area with catch rates >150kg began to decrease in 1997, while the interval with the highest catch rates (>450) continued to increase (Figure 5 upper). Also, areas of

intermediate catch rates (151-250, 251-350, and 351-450 units) peaked in sequence (Figure 5, lower) as the resource increased in density. The pattern changed from 2001-2002 as the area of highest concentration (>450) continued to increase while all other areas decreased in size. These have remained relatively small since, while the area of highest concentration has remained large and stable.

Interpretation: The very large and widespread 2001 year class has become available to the fishery before the trend of increasing areas of high catch rates attributed to the previous set of strong year classes (1994-95) could be reversed. Consequently, the area of highest catch rates and shrimp concentrations has remained high and the area with lower catch rates and shrimp concentrations has remained relatively low. The decrease in this indicator is therefore not a concern at this time but may be in the near future as the 2001 year class begins to die off and the following year classes are weaker as expected.

PRODUCTION

RV Abundance at Age 2

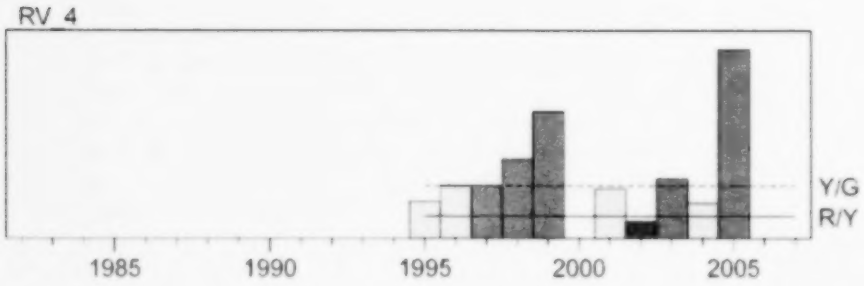


The index of two-year old shrimp has decreased every year since the 2003 record value associated with the large 2001 year class (Table 5). The 2005 year class at age 2 in the 2007 survey is the smallest on record. Good recruitment associated mainly with the 2001 year class is being followed by lower recruitment, similar to what followed the good 1993-1995 year classes. This cycle of good followed by lower recruitment is a familiar pattern in established shrimp fisheries. Population modelling suggests that this may be a fishing effect, particularly when the cycle length approximates the life span. It also suggests lower population stability and the continued need for good monitoring and precaution.

The weakness of the 2005 year class is supported by the belly-bag results which show that the 2005 year class at age 1 in the 2006 survey is the weakest of this series. (Table 5, Figure 10). The 2006 year class is stronger, about average for the short (6 yr) series if the exceptional 2001 year class is excluded. Belly-bag samples generally substantiate results from the main trawl (Figure 11) and indicate weaker year classes following the strong 2001 year class.

Interpretation: Recruitment following the pulse associated with the 2001 year class is relatively low. This may be a cyclical phenomenon associated with fishing, environmental forcing, or both, and lower population stability.

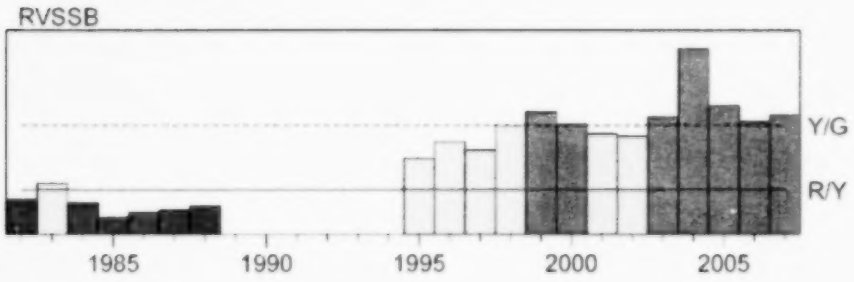
RV Abundance at Age 4



The abundance of age 4 shrimp increased from below average in 2004 to the highest on record, reflecting the recruitment of the strong 2001 year class to what usually is the oldest male age group in the population. However, in 2006 and 2007 this age (2002-2003 year classes) was not differentiated from the large mode attributed mainly to the 2001 year class. A similar situation occurred in 1996, following the large 1995 year class (Table 5, Figure 11). Changes in this indicator reflect the apparent cyclical recruitment pattern seen with the age 2 indicator above.

Interpretation: The abundance of 4 year old shrimp that are usually in their last year as males and will provide the bulk of the catch in next 2+ years could not be differentiated from the large 2001 year class mode for the last 2 years. Although the abundance of 4 year olds may be low, the large 2001 year class (now 6 years old), continues to grow slowly, providing recruits to the fishery over several years. Although some members of this year class began to change sex in 2007, many are still in the male phase and will continue to change sex in 2008, 2 years later than usual.

RV Spawning Stock Biomass (Females)

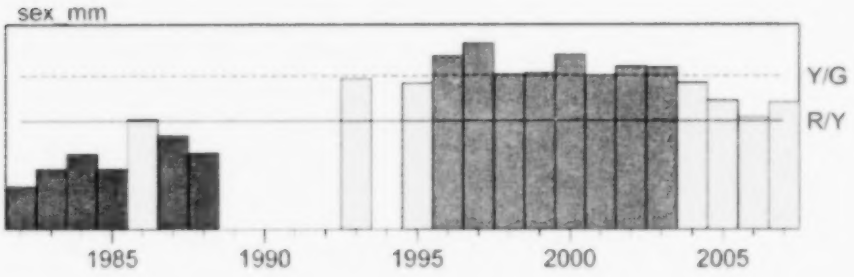


The research vessel spawning stock biomass has been stable at a high level since 2003, including a record high in 2004. It remains well above the long term average and is considerably higher than during the population increase during the mid to late 1990s.

Figure 16 suggests that higher spawning stock biomasses are associated with better recruitment; for example, the large 2001 year class was produced by one of the highest spawning stock biomasses and female population numbers of the series, and the largest index of egg production. Similarly, the weak 1996 year class was produced by the smallest spawning stock biomass and female population, and one of the lowest indices of egg production. On the other hand, the record spawning stock biomass of 2004 appears to have produced a poor year class, as did the spawning stock that produced the 2000 year class. This may be indicative of a "dome" shaped stock recruitment curve, but the variability around any fitted model precludes its use for management decisions at this time.

Interpretation: The spawning stock biomass remains high and is expected to remain high in 2008 as the large 2001 year class continues to change sex. There is no concern at present for recruitment overfishing from this point of view, but the lower recruitment indices of the last view years despite high spawning stock biomasses indicate that recruitment is at least partially determined by other factors. With the spawning stock largely comprised of this year class and weaker year classes following it, there is concern that SSB will decrease significantly and rapidly after its passage through the population.

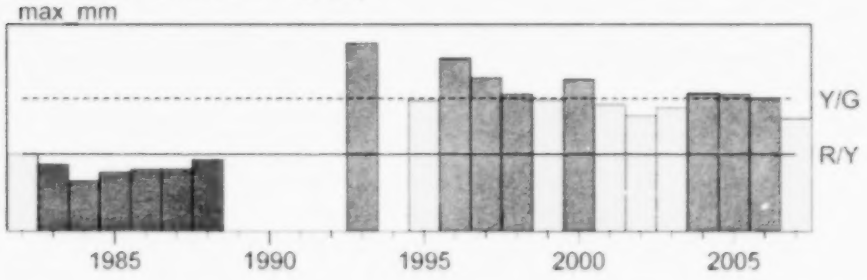
Average Size at Sex Transition (L_t)



This indicator has been decreasing since 2002 and remains significantly lower than the large sizes at sex change recorded in the mid to late 1990s, but not as low as the period of low abundance during the 1980s (Figure 13A). It increased in all areas in 2007.

Interpretation: The increase in size at sex change in 2007 may be due to the increasing number of male year classes due to slower growth of the large 2001 year class. This may continue in 2008 and would be a positive development as larger females produce more eggs. However, the longer term decreasing trend in this indicator is a concern, both biologically and economically.

Average Maximum Size (L_{max})

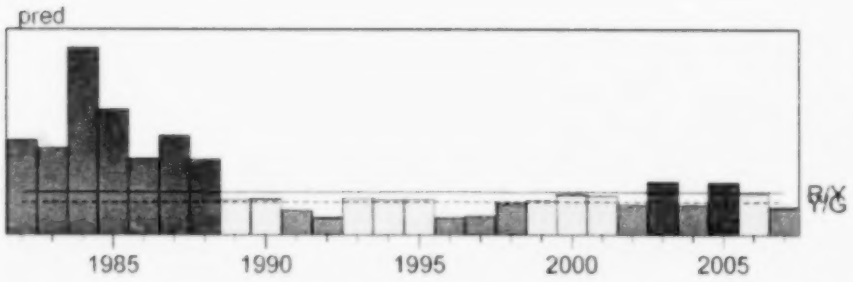


Maximum size remains substantially higher than the period of low abundance and faster growth during the 1980s. As with size at transition, annual changes are often reflected in all regions (Figure 13B). Although there has been no clear recent trend in this indicator a decreasing trend since 1995 is evident.

Interpretation: There has been no clear recent decreasing trend in maximum size similar to that seen for size at sex transition. Both metrics are expected to change more or less in parallel but with a lag for maximum. As suggested for size at sex transition above, maximum size may increase because of the slower growth and delayed sex change of the 2001 year class, many individuals of which now have two extra years to grow in the male phase; however, this is also

influenced by longevity and size/age specific mortality rates. The longer term decreasing trend in this indicator is a concern, both biologically and economically.

Predation

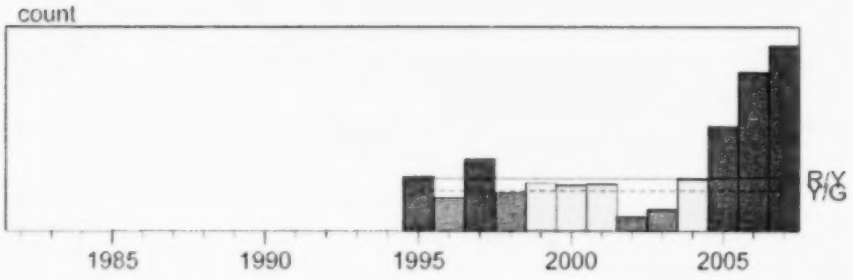


Groundfish abundance remains well below the high levels during the 1980s when the shrimp population was low.

Interpretation: Natural mortality (M) due to predation remains well below the high values of the 1980s that probably contributed to the low shrimp abundances during that period.

FISHING IMPACTS

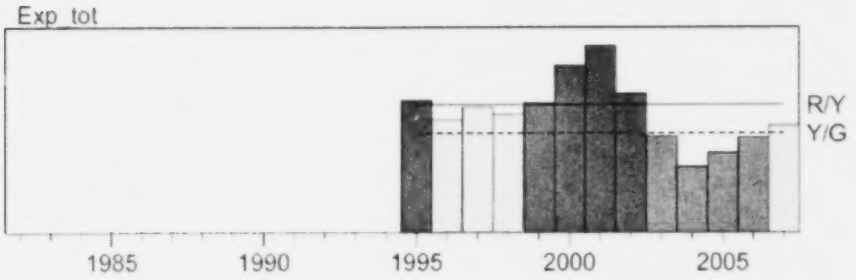
Commercial Counts



These fishery-derived data reflect the strong recruitment events evident in survey data (compare with age 2 and 4 recruitment). Counts have increased significantly since 2004, as the 2001 year class became more catchable. The catch-at length (Figure 9) shows the relatively large numbers of small shrimp from the 2001 year class caught in 2004-2007 and survey results show that it continues to be widespread throughout the stock area (Figure 12).

Interpretation: Fishers continue to have difficulty remaining below the counts that command the best prices from buyers, which probably exacerbated the problem of low prices generally experienced during the last 3 years. There is some concern for growth overfishing. Somewhat lower counts may occur in 2008 as the 2001 year class continues to grow and enter the female phase, but the extent of this will be determined by recruitment, growth and mortality rates.

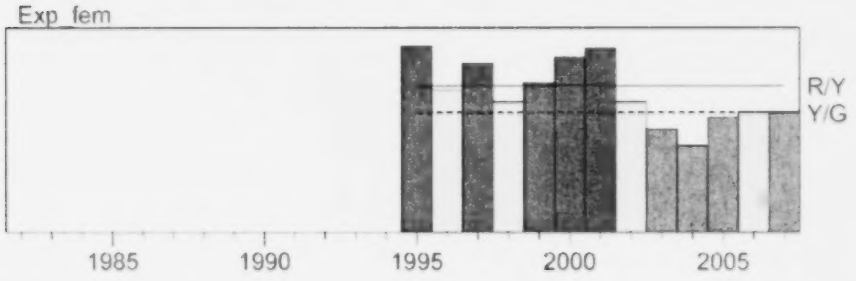
Exploitation Index



Total exploitation has been increasing since 2004, and it increased again in 2007 due to the continued high TAC and increase in the catch; however, it remained below the long-term average. Exploitation rates were somewhat less evenly distributed among fishing areas than in 2006, with a further notable increase in exploitation in SFA 14 caused by both increased fishing pressure and a decrease in biomass in this area (Table 6) which may be cause and effect. Conversely, exploitation has been decreasing in SFA 13 in the last few years and was well below average in 2007.

Interpretation: Overall exploitation remains relatively low and relatively evenly distributed over the fishing grounds. SFA 14 experienced heavier exploitation than it has for some time. The large decrease in biomass in this area may be due to increasing exploitation during the last 3 years. Exploitation in SFA 13 continues to drop after fishing pressure peaked here in 2007.

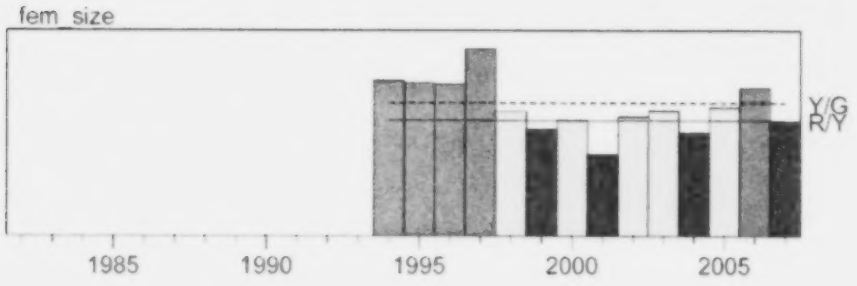
Female Exploitation Rate



Female exploitation has been relatively stable in recent years and remains below the long-term average. Length specific exploitations from 1995-2006 (Figure 15) indicate that the exploitation rate index of the smallest (<19mm CL) and largest (>26mm CL) sized shrimp increased substantially in 2007 to above average.

Interpretation: Female exploitation rates remain below average. The increase in the exploitation rate of the smallest shrimp is due to decreased recruitment and sustained fishing effort. Growth overfishing is a concern, in addition to increased mortality of the incoming weaker year classes.

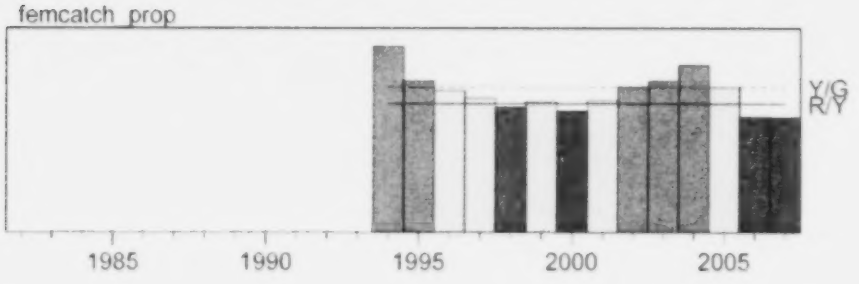
Mean Size of Females in Catch



The average size of females in the catch decreased in 2007 and remains below the relatively high values seen since the mid 1990s.

Interpretation: The average size of females in the catch has decreased as the larger animals were selectively removed from the population by the fishery. Since fecundity is directly related to size, this, in combination with other factors (fishing during the ovigerous period, increased female exploitation, size at sex change and maximum size), may have impacted the reproductive capacity of the population. The decrease in 2007 may be related to recruitment of the 2001 year class to the female population which started to change sex this year. As the first to change, these shrimp are probably smaller than the bulk of the year class that has yet to change sex and that will benefit from an additional year(s) of growth in the male phase.

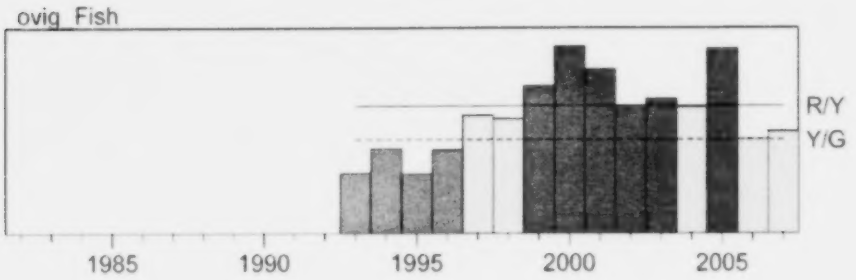
Proportion of Females in Catch



The proportion of females in the catch remained low in 2007.

Interpretation: The proportion of females in the catch decreased as a group of strong year classes (1993-1995) recruited to the fishery and more shrimp were caught as males. It has been low during the last 2 years as more males were caught from the 2001 year class, exacerbated by its delay in sex change. Growth overfishing is a concern.

Fishing During Ovigerous Period

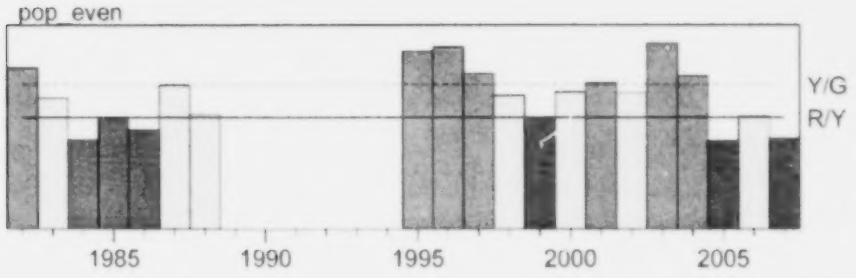


Fishing during the ovigerous period increased significantly from the early 1990s to a maximum in 2000 due to the longer time required to catch increasing TACs by a relatively small fleet of vessels. In addition, quota transfers have occurred and many vessels fished several individual quotas, further extending the length of the season. This indicator improved in 2002-2004 as the lower TAC was again caught mainly during the non-ovigerous summer period. Fishing during the ovigerous period increased in 2005 because of the TAC increase and decreased effort during the summer months due to market conditions. However, it has decreased during the last two years, perhaps because fishers endeavoured to catch more shrimp during favourable weather before the anticipated summer closure. The monthly distribution of catches, effort and catch rates are shown in Figure 8.

Interpretation: Fishing during the ovigerous period may have impacted population reproductive potential in 2005 by removing ovigerous females before their eggs had hatched. The degree to which this is a problem has not been established; however, it is worth noting that the large 2005 spawning stock biomass has produced one of the lowest year classes (2006) in the survey series (Figure 16).

ECOSYSTEM

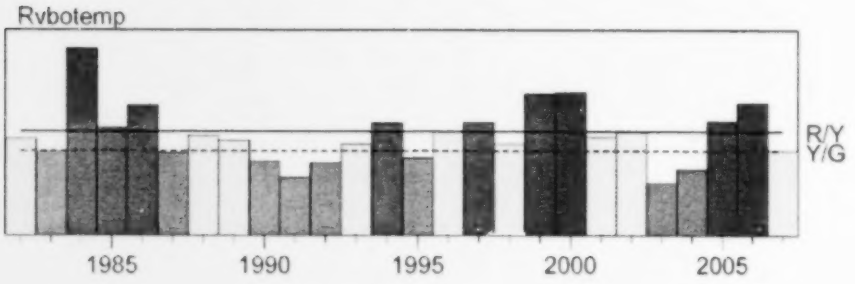
Population Age-length Evenness



Population evenness was high at the beginning of the survey series in 1995 when the fishery was relatively new (it first attained the TAC only in 1994). It declined in the late 1990s as the large 1994-1995 year classes dominated the population and has been very low during the last three years as the 2001 year class dominated, with values comparable to those seen during the low population levels in the mid 1980s.

Interpretation: A relatively large proportion of the population is currently concentrated in only one year class, a situation that may be unstable. This may lead to population fluctuations of greater magnitude than the recruitment pulses already experienced in this fishery.

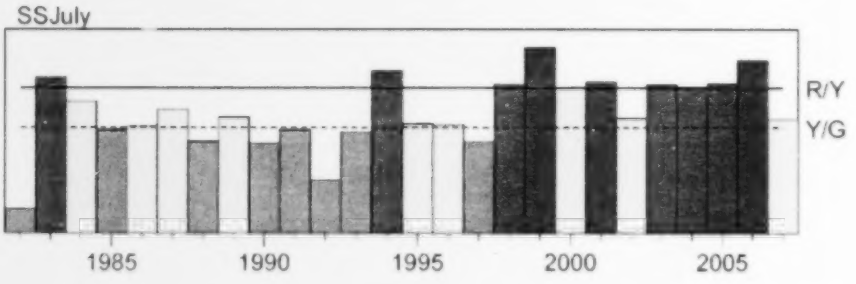
RV (Groundfish Survey) Bottom Temperatures



Bottom temperatures on the shrimp grounds were relatively high during the 1980s when the shrimp population was low, and it was low during the population increase of the 1990s. Higher temperatures preceded the population downturn in 2001-2003. Temperatures appear to have increased since 2003 but were cooler in 2007.

Interpretation: The higher bottom temperatures in 2005-2006 may be of concern if they are part of a trend, but this has not been established.

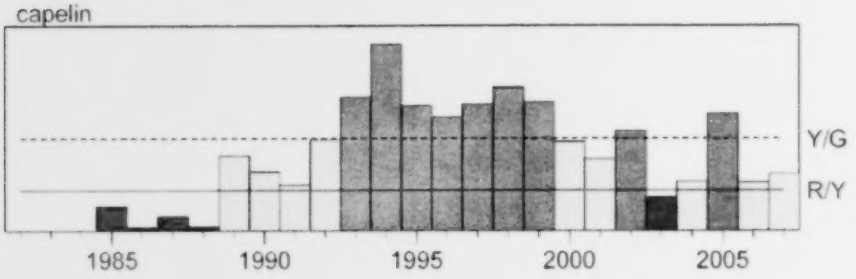
July Sea Surface Temperatures (SST)



At the southern limits of distribution (Gulf of Maine), surface temperatures are inversely related to shrimp abundance with a lag of 4-5 years. On the Scotian Shelf, the below average temperatures prevalent during the late 1980s and early 1990s may have facilitated the high abundances in the mid to late 1990s associated with the strong 1994-1995 year classes. However, at least one exceptional recruitment event occurred recently despite relatively high SSTs.

Interpretation: The warm water temperatures since the late 1990s may have contributed to the lower than average recruitments following the 2001 year class.

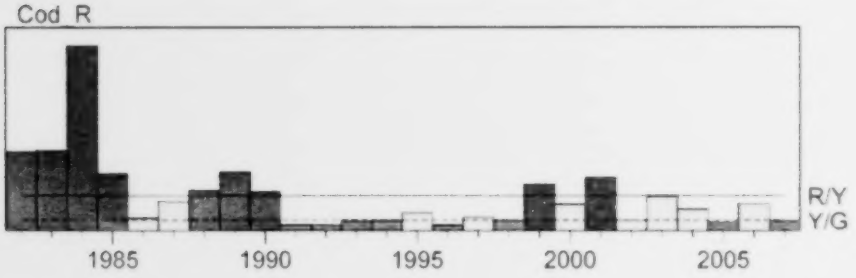
RV Capelin Abundance



During the last 8 years, capelin abundance has been lower on average than the relatively high values between 1993 to 1999. However, they remain considerably higher than during the period of low shrimp abundance during the 1980s.

Interpretation: Environmental/ecological conditions which result in high production of capelin and shrimp have not been as favourable since 2000, but they are better than during periods of poor shrimp and capelin production.

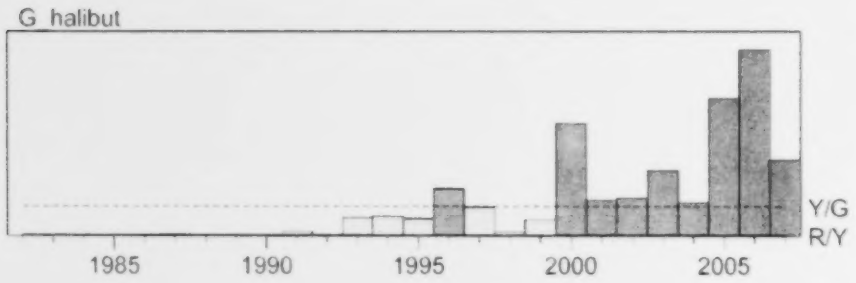
Cod Recruitment



Cod recruitment (<30cm) remains well below values seen in the 1980s.

Interpretation: Environmental conditions continue to be less favourable for cod and more favourable for shrimp. Natural mortality for shrimp due to cod predation is likely to remain low for some time.

Greenland Halibut Recruitment

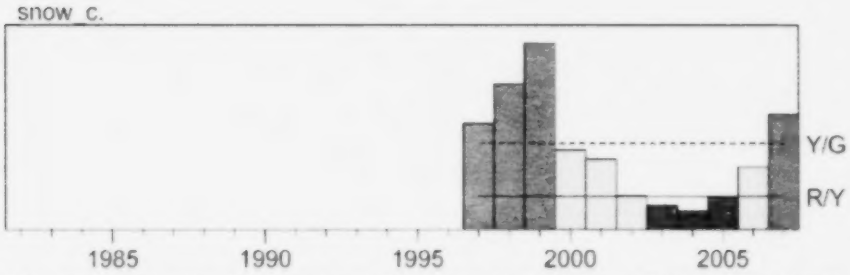


Greenland halibut <30cm continue to be abundant on the Eastern Scotian Shelf and appear to have increased significantly during the last 3 years. This species was rarely found during the warmer period of the 1980s when shrimp and capelin were also low in abundance. Note that the

relationship of the shrimp resource to this indicator is ambivalent since Greenland halibut are also known predators of shrimp.

Interpretation: Conditions still appear to be favourable for Greenland halibut and shrimp, but the increased abundance of halibut may be impacting on the shrimp population by increasing predation and natural mortality.

Snow Crab Recruitment

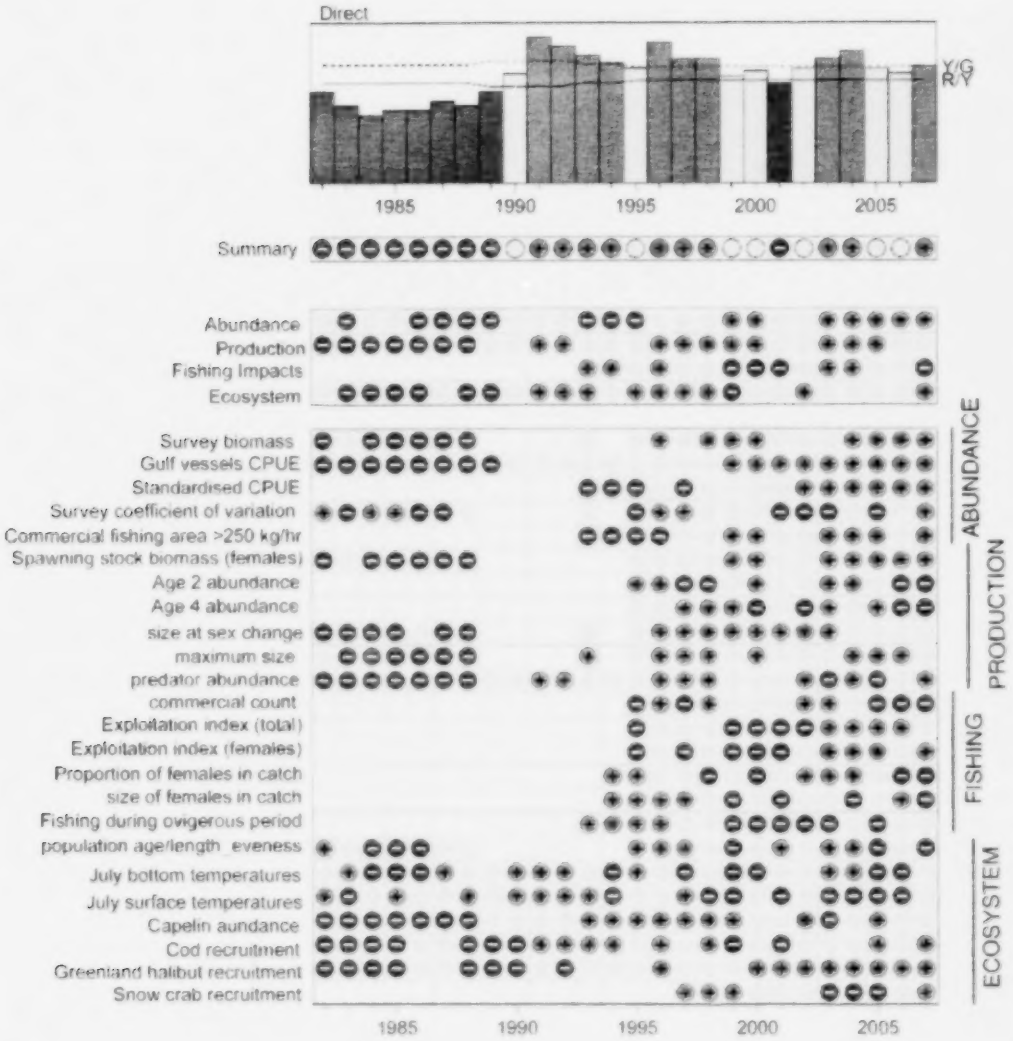


The male pre-recruit index from the snow crab survey off southern Cape Breton decreased from 1999 to 2004, but it has been increasing since. Snow crab abundance, as with Greenland halibut and capelin, tend to track shrimp abundance in the long term; however, snow crab have considerably longer longevities and population cycles.

Interpretation: The decrease in snow crab recruitment from 1999-2004 is beginning to reverse, suggesting that longer term environmental conditions for crab and shrimp are still favourable.

Traffic Light Summary

Note: the overall summary value is derived by a simple averaging process which does not account for complex interactions between indicators which may be occurring. Consequently, even the interpretation of individual indicators must be approached cautiously with regard to their relationship to stock health. Their placement within characteristics is also open to interpretation.



The overall summary turned green in 2007, after 2 yellow years; however, it was close to the green-yellow border. Characteristics have shown increasing yellow values since the generally favourable summaries of 2003-2004. Although 2 of the 4 characteristics were green in 2007 (an improvement from the single green characteristic the previous year), fishing impacts in 2007 was the first red characteristic in 6 years. The abundance characteristic and its indicators were all favourable (green) including the two spatial indicators. Abundance and biomass indicators remain high, are not of immediate concern, and support continued harvest at present levels for 2008. However, production remains yellow. These indicators remained unchanged except for

maximum size and predator abundance which exchanged yellow and green values. Low recruitment at age 2 and 4 continues to be the main concern in this area. Recruitment to the fishery and natural mortality of the 2001 year class will determine the biomass and population trajectory in 2008 and beyond. As indicated above, fishing impacts changed from yellow to red, mainly due to a decrease in the size of females in the catch. The decreasing size of shrimp both in survey and commercial indicators continues to be a concern as it may be due to fishing and impacting on the reproductive capacity of the population. The ecosystem characteristic improved in 2007 (yellow to green) due to improvements in a number of indicators including surface temperatures, bottom water temperatures, cod recruitment and snow crab recruitment. Predator abundance, which may be considered an ecosystem indicator but is presently listed under production, also improved. Consequently it seems that the environment continues to be generally favourable for shrimp on the eastern Scotian Shelf. The apparent downturn in recruitment in recent years may be due to density dependant factors, as suggested by stock recruitment relationships, unknown environmental factors, or fisheries impacts not considered, e.g., disturbance of mating behaviour. A new indicator filed under ecosystem characteristic (population age/length evenness) indicates that the population is now concentrated in fewer length categories than previously, which may contribute to less stable population dynamics.

BYCATCH

A requirement in the remit to update the bycatch data presented in last year's research document could not be fulfilled as there was no observer coverage during the 2007 fishery. The bycatch information available from the survey could not be updated (2005-2007) due to lack of resources (Koeller et al. 2006b).

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We again thank the captain and crew of MV *All Seven* for conducting the 2007 survey. Thanks also to the many fishers and buyers who provided fishery data such as counts, catch and effort data and, shrimp samples for laboratory analysis. Steve Smith provided statistical advice on bootstrap confidence intervals for survey data, and standardization of CPUEs. Mike Eagles provided the internal review of the manuscript. Angelica Silva and Kurtis Trzcinski acted as external reviewers during the RAP meeting and provide many useful comments.

REFERENCES

Caddy, J.F., E. Wade, T. Surette, M. Hebert, and M. Moriyasu. 2005. Using an empirical traffic light procedure for monitoring and forecasting in the Gulf of St. Lawrence fishery for the snow crab, *Chionoecetes opilio*. Fish. Res. 76: 123-145.

Charnov, E., and U. Skuladottir. 2000. Dimensionless invariants for the optimal size (age) of sex change. Evol. Ecol. Res. 2: 1067-1071.

Frank, K.T., J. Simon, and J.E. Carscadden. 1994. Recent excursions of capelin (*Mallotus villosus*) to Scotian Shelf and Flemish Cap during anomalous hydrographic conditions. NAFO SCR Doc. 94/68.

Gavaris, S. 1980. Use of a multiplicative model to estimate catch rate and effort from commercial data. J. Fish Aquat. Sci. 37: 2272-2275.

Halliday, R.G., and P.A. Koeller. 1981. A history of Canadian groundfish trawling surveys and data usage in ICNAF Divisions 4TVWX; pp. 27-41. In: W.G. Doubleday and D. Rivard (Eds). Bottom Trawl Surveys. Can. Spec. Publ. Fish. Aquat. Sci. 58.

Halliday, R.G., L.P. Fanning, and R.K. Mohn. 2001. Use of the traffic light method in fishery management planning. Can. Sci. Advis. Sec. Res. Doc. 2001/108.

Koeller, P. 1996a. Aspects of the biology of pink shrimp, *Pandalus borealis* Krøyer on the Scotian Shelf. DFO Atl. Fish. Res. Doc. 96/9.

Koeller, P. 1996b. The Scotian Shelf shrimp fishery in 1995. DFO Atl. Fish. Res. Doc. 96/8.

Koeller, P. 1996c. Results from the experimental shrimp trap fishery 1995. DFO Atl. Fish. Res. Doc. 96/10.

Koeller, P., M. Covey, and M. King. 1996d. The Scotian Shelf shrimp (*Pandalus borealis*) fishery in 1996. DFO Atl. Fish. Res. Doc. 96/128.

Koeller, P., M. Covey, and M. King. 1997. The Scotian Shelf shrimp (*Pandalus borealis*) fishery in 1997. DFO Atl. Fish. Res. Doc. 97/125.

Koeller, P., M. Covey, M. King, and S.J. Smith. 1998. The Scotian Shelf shrimp (*Pandalus borealis*) fishery in 1998. DFO Stock Assess. Res. Doc. 98/150.

Koeller, P., M. Covey, and M. King. 1999. The Scotian Shelf shrimp (*Pandalus borealis*) fishery in 1999. DFO Stock Assess. Res. Doc. 99/172.

Koeller, P. 2000. Relative importance of environmental and ecological factors to the management of the northern shrimp fishery (*Pandalus borealis*) on the Scotian Shelf. J. Northw. Atl. Fish. Sci. 27: 37-50.

Koeller, P., R. Mohn, and M. Etter. 2000a. Density dependant sex change in pink shrimp, *Pandalus borealis*, on the Scotian Shelf. J. Northw. Atl. Fish. Sci. 27: 107-118.

Koeller, P., L. Savard, D. Parsons, and C. Fu. 2000b. A precautionary approach to assessment and management of shrimp stocks in the Northwest Atlantic. J. Northw. Atl. Fish. Sci. 27: 235-247.

Koeller, P., M. Covey, and M. King. 2001. Northern shrimp (*Pandalus borealis*) on the eastern Scotian Shelf – Review of the 2000 fishery and outlook for 2001. DFO Can. Sci. Advis. Sec. Res. Doc. 2001/003.

Koeller, P., M. Covey, and M. King. 2002. A new traffic light assessment for northern shrimp (*Pandaus borealis*) on the eastern Scotian Shelf. DFO Can. Sci. Advis. Sec. Res. Doc. 2002/006.

Koeller, P., M. Covey, and M. King. 2003. An assessment of the eastern Scotian Shelf shrimp stock and fishery for 2003. DFO Can. Sci. Advis. Sec. Res. Doc. 2003/005.

Koeller, P., M. Covey, and M. King. 2003b. Is size at transition a measure of growth or abundance in Pandalid shrimp? Fish. Res. 65: 217-230.

Koeller, P., M. Covey, and M. King. 2004. An assessment of the eastern Scotian Shelf shrimp stock and fishery for 2003 and outlook to 2004. DFO Can. Sci. Advis. Sec. Res. Doc. 2004/001.

Koeller, P. 2006. Inferring shrimp (*Pandalus borealis*) growth characteristics from life history stage structure analysis. J. Shell. Res. 25: 595-608.

Koeller, P., M. Covey, and M. King. 2005. An assessment of the eastern Scotian Shelf shrimp stock and fishery for 2004 and outlook to 2005. DFO Can. Sci. Advis. Sec. Res. Doc. 2005/001.

Koeller, P., M. Covey, and M. King. 2006a. An assessment of the eastern Scotian Shelf shrimp stock and fishery for 2005 and outlook to 2006. DFO Can. Sci. Advis. Sec. Res. Doc. 2006/001.

Koeller, P., M. Covey, and M. King. 2006b. An assessment of the eastern Scotian Shelf shrimp stock and fishery in 2006 and outlook for 2007, including an estimate of bycatch and evaluation of alternative fishery independent abundance indicators. DFO Can. Sci. Advis. Sec. Res. Doc. 2006/090.

Macdonald, P.D.M., and T.J. Pitcher. 1979. Age-groups from size-frequency data: A versatile and efficient method of analysing distribution mixtures. J. Fish. Res. Board Can. 36, 987-1001.

Mohn, R., J. Black, and P. Koeller. 2001. Traffic Light Indicators. BIO review 2000.

Ouellet, P., L. Savard, and P. Larouche. 2007. Spring oceanographic conditions and northern shrimp, *Pandalus borealis*, recruitment success in the north-western Gulf of St. Lawrence. Mar. Ecol. Prog. Ser. 339: 229-241.

Shumway, S.E., H.C. Perkins, D.F. Schick, and A.P. Stickney. 1985. Synopsis of biological data on the pink shrimp, *Pandalus borealis* Krøyer, 1838. NOAA Tech. Rept. NMFS 30.

Smith, S.J. 1997. Bootstrap confidence limits for groundfish trawl survey estimates of mean abundance. Can. J. Fish. Aquat. Sci. 54: 616-63.

Table 1. TACs (trawls) and catches (trawls and traps) from the eastern Scotian Shelf shrimp fishery 1980-2006.

	TAC		Catch					
	Trawl	Trap	Trawl				Trap	
			SFA					
			13	14	15	Total		Total
1980	5021		491	133	360	984		984
1981	-		418	26	10	454		454
1982	4200		316	52	201	569		569
1983	5800		483	15	512	1010		1010
1984	5700		600	10	318	928		928
1985	5560		118	-	15	133		133
1986	3800		126	-	-	126		126
1987	2140		148	4	-	152		152
1988	2580		75	6	1	82		82
1989	2580		91	2	-	93		93
1990	2580		90	14	-	104		104
[1]**1991**	2580		81	586	140	804		804
1992	2580		63	1181	606	1850		1850
[2]**1993**	2650		431	1279	317	2044		2044
[3]**1994**	3100		8	2656	410	3074		3074
1995	3170		168	2265	715	3148	27	3175
1996	3170		55	2299	817	3171	187	3358
1997	3600		570	2422	583	3574	222	3797
1998	3800		562	2014	1223	3800	131	3931
1999	4800	200	717	1521	2464	4702	149	4851
2000	5300	200	473	1822	2940	5235	201	5436
2001	4700	300	692	1298	2515	4505	263	4768
2002	2700	300	261	1553	885	2699	244	2943
2003	2700	300	612	1623	373	2608	157	2765
2004	3300	200	2041	755	376	3172	96	3268
2005	4608	392	1190	1392	1054	3636	9	3645
2006	4608	392	846	1997	1111	3954	32	3986
[4]**2007**	4800	200	400	2370	1720	4490	10	4500

[1] Nordmore separator grate introduced.
[2] Overall TAC not caught because TAC for SFA 14 and 15 was exceeded.
[3] Individual SFA TACs combined.
[4] Preliminary to Nov. 22, a projected catch of 4,500mt was used to calculate exploitation rates, etc.

Table 2. Number of active vessels and total licences (in brackets) for the eastern Scotian Shelf shrimp fishery.

Year	Trap S-F[1]	Trawl S-F[2]	Trawl Gulf[3]
1995	4	24(23)	6(23)
1996	9(17)	21(24)	6(23)
1997	10(17)	18(23)	6(23)
1998	15(26)	17(28)[4]	10(23)[5]
1999	15(22)	19(28)[4]	10(23)[5]
2000	12(21)	18(32)[6]	10(23)[5]
2001	10(28)	18(28)[4]	10(23)[5]
2002	10(14)[7]	15(23)	6(23)
2003	9(14)	14(23)	5(23)
2004	6(14)	14(23)	6(23)
2005	2(14)	20(28)[8]	7(24)[9]
2006	5(14)	18(28)	7(24)
2007	2(14)	20(28)	7(24)

[1] All but one active trap licences are vessels < 45'. They receive about 8% of the TAC.
[2] These vessels receive about 70% of the TAC according to the management plan. Inactive NAFO 4X licences (15) not included in total.

[3] All licences 65-100' LOA. Eligibility to fish in Scotia-Fundy for about 23% of the TAC.

[4] Temporary allocation divided among 5 vessels.

[5] Temporary allocation divided among 4 vessels.

[6] Temporary allocation divided among 9 licences.

[7] Nine (9) licences were made permanent for 2002. The reduction in the total number of trap licences is due to cancellation of some non-active exploratory licences
[8] Five (5) temporary licences made permanent.

[9] One (1) temporary licence made permanent

Table 3. Input data for traffic light analysis.

Indicators	RV_CPUE	G_CPUE	St_CPUE	RV_CV	Comm_area	RVSSB	RV_2	RV_4	sex_mm	max_mm	pred	count	Exp_tot	Exp_fem	femcatch_prop	fem_size	ovig_Fish	pop_even	Rvbotemp	SSJuly	capelin	Cod_R	G_halibut	snow_c
Action	Pctile	Pctile	Pctile	Pctile	Pctile	Pctile	Pctile	Pctile	Pctile	Pctile	Pctile	Pctile	Pctile	Pctile	Pctile	Pctile	Pctile	Pctile	Pctile	Pctile	Pctile	Pctile	Pctile	Pctile
Indirect																								
Rule	abundance	(production ==		red)	+																			
Direct																								
Overwts	1	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Maxwts	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Level_YG	0.66	0.66	0.66	0.33	0.66	0.66	0.66	0.66	0.66	0.66	0.33	0.33	0.33	0.33	0.66	0.66	0.33	0.66	0.33	0.33	0.66	0.33	0.66	0.66
Level_RY	0.33	0.33	0.33	0.66	0.33	0.33	0.33	0.33	0.33	0.33	0.66	0.66	0.66	0.66	0.33	0.33	0.66	0.33	0.66	0.66	0.33	0.66	0.33	0.33
Charactenstics	Polarity																							
Abundance	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Production	0	0	0	0	0	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0
FishingM	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	0	0	0	0	0	0	0
Ecosystem	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1
Year																								
1982	34.5	128	NAN	66.54235	NAN	5040.7	NAN	NAN	21.71567	28.23559	179.29	NAN	NAN	NAN	NAN	NAN	NAN	0.808033	2.569091	9.6667	0	2.3846	0	NAN
1983	71.5	127.7	NAN	86.01369	NAN	7323.1	NAN	NAN	22.10738	28.03171	164.05	NAN	NAN	NAN	NAN	NAN	NAN	0.773812	2.220909	15.15	0	2.4151	0	NAN
1984	39	109.5	NAN	55.35139	NAN	4461	NAN	NAN	22.4624	27.6918	353.25	NAN	NAN	NAN	NAN	NAN	NAN	0.726571	4.954444	14.14	0	5.569	0.060764	NAN
1985	17	75.4	NAN	60.47674	NAN	2417.7	NAN	NAN	22.11304	27.87091	236.37	NAN	NAN	NAN	NAN	NAN	NAN	0.750052	2.864444	12.96	1.5542	1.7091	0.051471	NAN
1986	23	87.3	NAN	113.1413	NAN	3187.9	NAN	NAN	23.26099	27.93519	144.33	NAN	NAN	NAN	NAN	NAN	NAN	0.737725	3.451176	13.118	0.1344	0.3683	0.085784	NAN
1987	26.5	90.7	NAN	89.20279	NAN	3424.5	NAN	NAN	22.89225	27.93636	187.04	NAN	NAN	NAN	NAN	NAN	NAN	0.788656	2.192857	13.808	0.7652	0.8659	0.162037	NAN
1988	31.5	86.1	NAN	70.19206	NAN	4047	NAN	NAN	23.48061	28.11905	142.81	NAN	NAN	NAN	NAN	NAN	NAN	0.755248	2.645455	12.483	0.1727	1.1947	0.057566	NAN
1989	NAN	133.4	NAN	NAN	NAN	NAN	NAN	NAN	NAN	NAN	66.581	NAN	NAN	NAN	NAN	NAN	NAN	NAN	2.517273	13.488	18.377	1.7535	0	NAN
1990	NAN	134.5	NAN	NAN	NAN	NAN	NAN	NAN	NAN	NAN	67.326	NAN	NAN	NAN	NAN	NAN	NAN	NAN	1.973043	12.4	9.2281	1.1632	0	NAN
1991	NAN	197.9	NAN	NAN	NAN	NAN	NAN	NAN	NAN	NAN	46.906	NAN	NAN	NAN	NAN	NAN	NAN	NAN	1.5375	12.965	5.0715	0.1659	0.463863	NAN
1992	NAN	176.3	NAN	NAN	NAN	NAN	NAN	NAN	NAN	NAN	32.1	NAN	NAN	NAN	NAN	NAN	NAN	NAN	1.92069	10.863	34.878	0.1691	0.084541	NAN
1993	75	193	189.4972	80.32	31	NAN	NAN	NAN	24.21605	30.4525	68.529	NAN	NAN	NAN	NAN	NAN	12.04614	NAN	2.4245	12.858	193.36	0.2868	1.860152	NAN
1994	NAN	202.4	267.8718	NAN	48	NAN	NAN	NAN	NAN	NAN	66.166	NAN	NAN	NAN	0.889796689	26.04963	18.20267	NAN	2.976	15.42	1563.9	0.2999	1.978313	NAN
1995	173	233.8	234.7716	82.84489	71	10912	358.5	875.92	24.1096	29.30833	66.52	55.92	13.441	21.0351	0.724602874	26.02959	11.71402	0.826895	2.048214	13.195	138.62	0.5358	1.735172	NAN
1996	213.5	245.9	331.7434	64.87851	99	13368	307.3	1247.6	24.7413	30.13929	32.558	54.47	11.498	16.1062	0.680096615	26.00976	16.37874	0.83186	2.738148	13.17	87.534	0.1611	4.784847	NAN
1997	193	245.5	312.8279	53.4554	146	12101	128.9	1257.5	25.04026	29.75763	35.85	57.16	12.8	19.0801	0.642840916	26.44078	23.23776	0.802049	2.996296	12.468	146.64	0.396	2.906094	7061.8
1998	238.5	341	397.5736	74.41755	209	15707	39.89	1883.7	24.31246	29.43232	59.866	54.83	12.078	14.728	0.599315055	25.67582	22.58465	0.776629	2.437083	14.858	284.31	0.3068	0.41271	9691.2
1999	268.5	396	434.8695	72.1962	258	17607	165.6	3010.2	24.34782	29.31818	64.133	55.54	13.245	16.8957	0.625535397	25.4562	28.92315	0.749408	3.743571	16.38	159.96	1.3907	1.672614	12397
2000	233.5	396	476.2914	71.99518	242	15893	280.3	0	24.77178	29.72143	76.288	55.34	17.061	19.7862	0.578255807	25.56624	36.70458	0.780617	3.79	14.705	32.375	0.7869	11.43957	5290.41
2001	183.5	444	526.0566	126.0315	221	14476	174.9	1184.1	24.29452	29.22344	73.28	55.42	19.051	20.7233	0.631051858	25.14556	32.11821	0.791542	2.618125	14.957	15.994	1.5792	3.659454	4671.95
2002	161.4	572	600.8073	111.1492	192	14133	134.00	399.17	24.49541	29.00357	57.301	53.15	14.167	14.7178	0.69737234	25.60901	25.13581	0.780038	2.737778	13.441	49.85	0.316	3.875452	2220.35
2003	204.4155	697.085	613.5888	104.4793	265	16916	576.74	1411.1	24.46898	29.16607	100.65	53.65	9.8293	11.6276	0.725179493	25.68051	26.44734	0.836181	1.39	14.829	2.698	1.0255	6.690889	1586.45
2004	353.7	810.906	615.1723	78.00419	263	26856	354.1	839.46	24.11824	29.44167	57.455	55.75	6.6875	9.7501	0.80135842	25.41152	25.47267	0.799207	1.751176	14.726	5.9286	0.6415	3.436608	1224.54
2005	312.9	697	559.7649	83.01133	364	18587	187	4502.5	23.70755	29.43103	99.049	59.49	8.1381	12.9732	0.66352342	25.72156	29.51574	0.72517	3.027	14.875	99.407	0.2488	13.99674	2143.65
2006	275.2	739	751.4987	75.86295	296	16289	121.3	0	23.3233	29.35167	77.4674	63.23	10.551	13.5553	0.553890477	25.9628	29.21892	0.752791	3.497	15.855	5.7774	0.7953	18.92322	4176.9
2007	281	750	622.8923	66.3	335	17236	37	0	23.67049	28.95349	51.641	65.11	10.918	13.525	0.549453014	25.55792	20.00236	0.728038	2.251356	13.418	8.4538	0.2914	7.769687	7650.61

Table 4. Set statistics from DFO-industry survey AS0701 conducted by MV All Seven June 1 - 11 2007.

SET	SFA	DATE	LAT.	LONG.	SPEED (kts)	DIST. (n. m.)	DUR. (min)	WING. (m)	DEPTH (fth)	TEMP (°C)	RAW CATCH	stand. catch (kg)	DENSITY (gm/m² or m.t./km2)	
1	15	01-Jun-2007	44°59.96	61°02.24	2.3	1.13	30	17.4	111	1.4	83	91.3	2.3	
2	15	01-Jun-2007	44°53.10	61°09.15	2.3	1.15	30	17.4	119	2.6	132	143.1	3.6	
3	15	01-Jun-2007	44°54.10	61°01.78	2.3	1.13	29	17.4	129	2.4	225	247.9	6.2	
4	15	01-Jun-2007	44°53.95	60°57.15	2.4	1.15	30	17.4	144	2.5	365	395.8	9.8	
5	15	01-Jun-2007	44°49.57	60°54.86	2.4	1.17	30	17.4	117	2.5	459	489.7	12.2	
6	15	01-Jun-2007	44°51.82	60°50.88	2.4	1.15	29	17.4	137	2.1	44	48.2	1.2	
7	15	01-Jun-2007	44°54.29	60°48.37	2.3	1.13	29	17.4	146	2.1	314	346.1	8.6	
8	15	01-Jun-2007	44°47.86	60°44.38	2.3	1.09	29	17.4	150	2.3	274	313.1	7.8	
9	15	01-Jun-2007	44°51.17	60°40.37	2.3	1.16	30	17.4	130	2.1	314	339.9	8.4	
10	15	02-Jun-2007	44°37.33	60°13.31	2.4	1.15	29	17.4	145	2.2	155	168.3	4.2	
11	15	02-Jun-2007	44°42.80	60°10.52	2.3	1.13	30	17.4	156	2.1	163	180.6	4.5	
12	15	02-Jun-2007	44°46.90	60°21.13	2.3	1.08	29	17.4	197	1.6	57	66.3	1.6	
13	15	02-Jun-2007	44°51.16	60°16.07	2.3	1.13	29	17.4	198	1.6	195	215.4	5.3	
14	15	02-Jun-2007	44°52.51	60°24.41	2.4	1.16	29	17.4	172	1.6	55	59.8	1.5	
15	15	02-Jun-2007	44°54.20	60°18.30	2.3	1.12	29	17.4	120	1.6	269	300.8	7.5	
16	17	02-Jun-2007	45°16.85	60°19.25	2.4	1.12	30	17.4	103	1.8	235	262.3	6.5	
17	17	03-Jun-2007	45°15.98	59°51.90	2.3	1.12	30	17.4	126	1.8	225	251.0	6.2	
18	17	03-Jun-2007	45°20.34	60°00.73	2.4	1.13	29	17.4	118	1.9	220	243.5	6.0	
19	17	03-Jun-2007	45°24.37	59°54.91	2.3	1.14	29	17.4	114	1.9	418	460.4	11.4	
20	17	03-Jun-2007	45°23.41	59°44.09	2.3	1.12	29	17.4	107	2.1	88	96.9	2.5	
21	17	03-Jun-2007	45°39.49	59°52.34	2.3	1.11	29	17.4	105	1.1	0	0.5	0.0	
22	17	03-Jun-2007	45°36.05	60°02.05	2.4	1.12	29	17.4	99	1.4	55	61.6	1.5	
23	17	03-Jun-2007	45°32.29	60°01.99	2.3	1.10	29	17.4	104	1.6	142	161.0	4.0	
24	17	03-Jun-2007	45°34.01	60°14.35	2.3	1.09	29	17.4	80	1.6	482	551.3	13.7	
25	17	03-Jun-2007	45°33.95	60°21.63	2.3	1.11	29	17.4	99	1.8	427	481.9	12.0	
26	17	04-Jun-2007	45°33.89	60°23.20	2.3	1.14	30	17.4	104	1.5	356	390.5	9.7	
27	17	04-Jun-2007	45°25.03	60°42.39	2.3	1.11	29	17.4	71	1.5	263	295.6	7.3	
28	17	04-Jun-2007	45°27.49	60°44.75	2.3	1.12	29	17.4	79	1.4	303	337.5	8.4	
29	17	04-Jun-2007	45°25.91	60°52.10	2.3	1.13	29	17.4	81	1.2	328	364.6	9.1	
30	17	04-Jun-2007	45°22.45	61°01.75	2.3	1.11	29	17.4	60	1.1	132	148.0	3.7	
31	13	08-Jun-2007	45°36.13	59°05.61	2.3	1.13	29	17.4	126	3.5	178	197.1	4.9	
32	13	08-Jun-2007	45°39.23	58°59.81	2.4	1.12	29	17.4	122	3.6	38	41.9	1.0	
33	13	08-Jun-2007	45°38.12	58°52.38	2.4	1.17	30	17.4	132	3.6	58	62.1	1.5	
34	13	08-Jun-2007	45°41.36	58°48.14	2.4	1.15	29	17.4	118	3.6	88	95.4	2.4	
35	13	08-Jun-2007	45°42.59	58°59.14	2.3	1.12	29	17.4	134	3.7	278	309.2	7.7	
36	13	08-Jun-2007	45°47.02	58°55.67	2.3	1.12	29	17.4	113	3.6	373	418.0	10.4	
37	13	08-Jun-2007	45°49.10	58°47.87	2.3	1.10	29	17.4	104	3.8	485	550.1	13.7	
38	13	08-Jun-2007	45°51.77	58°42.97	2.4	1.17	30	17.4	105	4.0	288	307.1	7.6	
39	13	08-Jun-2007	45°50.42	58°35.44	2.4	1.12	29	17.4	104	3.8	106	118.7	2.9	
40	13	08-Jun-2007	45°47.49	58°41.95	2.3	1.13	30	17.4	132	3.7	190	208.8	5.2	
41	13	09-Jun-2007	45°47.61	58°30.63	2.4	1.14	30	17.4	107	3.7	10	10.9	0.3	
42	13	09-Jun-2007	45°42.85	58°25.19	2.4	1.15	30	17.4	117	3.9	170	184.1	4.6	
43	13	09-Jun-2007	45°39.05	58°17.40	2.4	1.13	29	17.4	133	3.2	138	152.3	3.8	
44	13	09-Jun-2007	45°34.02	58°20.89	2.4	1.12	29	17.4	159	3.2	71	79.0	2.0	
45	13	09-Jun-2007	45°34.21	58°34.46	2.3	1.12	29	17.4	132	3.3	59	66.0	1.6	
46	14	09-Jun-2007	44°55.82	58°43.21	2.4	1.15	30	17.4	120	1.6	59	63.9	1.6	
47	14	10-Jun-2007	44°54.96	58°20.96	2.3	1.11	29	17.4	111	2.1	794	890.8	22.1	
48	14	10-Jun-2007	44°50.56	58°31.90	2.4	1.16	30	17.4	114	1.6	494	532.5	13.2	
49	14	10-Jun-2007	44°47.74	58°38.44	2.3	1.13	29	17.4	159	1.5	388	428.5	10.6	
50	14	10-Jun-2007	44°46.63	58°53.87	2.3	1.09	29	17.4	118	1.4	484	552.8	13.7	
51	14	10-Jun-2007	44°39.94	59°01.56	2.4	1.12	29	17.4	123	1.0	495	552.4	13.7	
52	14	10-Jun-2007	44°50.68	59°03.34	2.3	1.12	30	17.4	117	1.1	500	556.6	13.8	
53	14	10-Jun-2007	44°47.92	59°11.26	2.4	1.14	30	17.4	138	1.0	347	379.5	9.4	
54	14	10-Jun-2007	44°50.17	59°28.25	2.4	1.13	29	17.4	119	1.6	576	639.2	15.9	
55	14	11-Jun-2007	44°41.76	59°34.32	2.4	1.10	29	17.4	119	1.9	335	380.7	9.5	
56	14	11-Jun-2007	44°42.46	59°46.73	2.4	1.16	30	17.4	117	2.1	150	161.8	4.0	
57	14	11-Jun-2007	44°41.75	59°59.32	2.3	1.07	29	17.4	140	2.6	208	243.0	6.0	
58	14	11-Jun-2007	44°47.15	59°58.54	2.4	1.11	29	17.4	137	2.5	244	274.8	6.8	
59	14	11-Jun-2007	44°51.43	59°42.53	2.4	1.14	29	17.4	133	1.7	265	291.2	7.2	
60	14	11-Jun-2007	44°54.06	59°54.78	2.4	1.14	29	17.4	129	2.6	375	409.5	10.2	

Table 5. Minimum survey population numbers at age from modal analysis. Numbers x 10-6.

	95	96	97	98	99	00	01	02	03	04	05	06	07	Average
1[4]								980	196	316	198	61	194	324.17
2	359	307	129	40	166	280	175	134	616	354	187	121	37	223.42
3	1046	276	1159	785	27	757	362	383	312	3118	652	880	482	787.69
4	876	1248	1257	1884	3010	0[3]	1184	399	1506	839	4502	0[3]	0[3]	1670.66
5+	1702	2162	1539	2047	1952	3374	2110	1847	1727	3324	2224	5106	5247	2643.16
TOTAL	3983	3993	4084	4755	5155	4412	3831	2763	4161	7636	7763	6169	5766	4892.11
4+ males[1]	1369	1971	1578	2243	3235	1784	1771	938	1526	1549	4956	3916	2351	2245.12
primiparous[2]	649	777	709	889	736	728	817	678	551	870	786	771	1739	823.10
multiparous	560	661	509	647	991	863	706	630	1188	1698	1183	480	1157	867.06
total females	1209	1438	1218	1535	1727	1591	1523	1308	1739	2568	1969	1251	2896	1690.16

[1] total population less ages 2,3 males, transitionals and females
i.e. males that will potentially change to females the following year

[2] includes transitionals

[3] 4 year olds of the 1996 and 2002, 2003 yc were not distinguishable in the MIX analysis.
these yc appear to be small and are contained in the age 3 or 5+ categories

[4] belly bag

Table 6. Survey biomasses, commercial shrimp catches and exploitation rates (catch/biomass) by survey strata (13-15, offshore part), and the inshore area (17), 1995-2007.

		1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
	13	4838	6838	5921	7188	9517	5866	4089	3114	7047	12184	9687	6129	7507
biomass	14	9068	12094	9472	11279	11040	9364	12325	12020	12035	20228	20035	18929	15957
	15	5300	6610	4737	4549	7807	7268	2073	2766	3751	4399	4378	5130	5345
	17	4415	3663	6221	9530	8262	9365	6541	2872	5296	11627	10333	7581	9622
	total	23621	29205	26351	32546	36626	31863	25028	20773	28130	48438	44433	37769	38431
	13	168	55	570	514	612	301	588	254	581	2003	1186	629	292
catch	14	2265	2299	2422	2012	1503	2009	1616	1553	1622	754	1441	1996	2310
	15	715	817	583	618	589	1609	1132	265	225	339	600	445	797
	17	0	0	0	787	2121	1498	1629	873	330	143	389	915	1100
	total	3148	3171	3575	3931	4825	5417	4965	2945	2758	3239	3616	3985	4500
	13	3.5	0.9	9.1	7.2	6.5	5.1	13.8	8.2	8.3	16.4	12.2	10.3	3.9
exploitation	14	25.2	20.1	24.1	17.8	13.7	21.5	12.6	12.9	13.5	3.7	7.2	10.5	14.5
	15	13.6	13.1	11.6	13.6	7.6	22.2	52.4	9.6	6.0	7.7	13.7	8.7	14.9
	17	0.0	0.0	0.0	8.3	25.8	16.1	23.9	30.4	6.2	1.2	3.8	12.1	11.4
	total	13.4	11.5	12.8	12.1	13.2	17.1	19.1	14.2	9.8	6.7	8.1	10.6	11.7

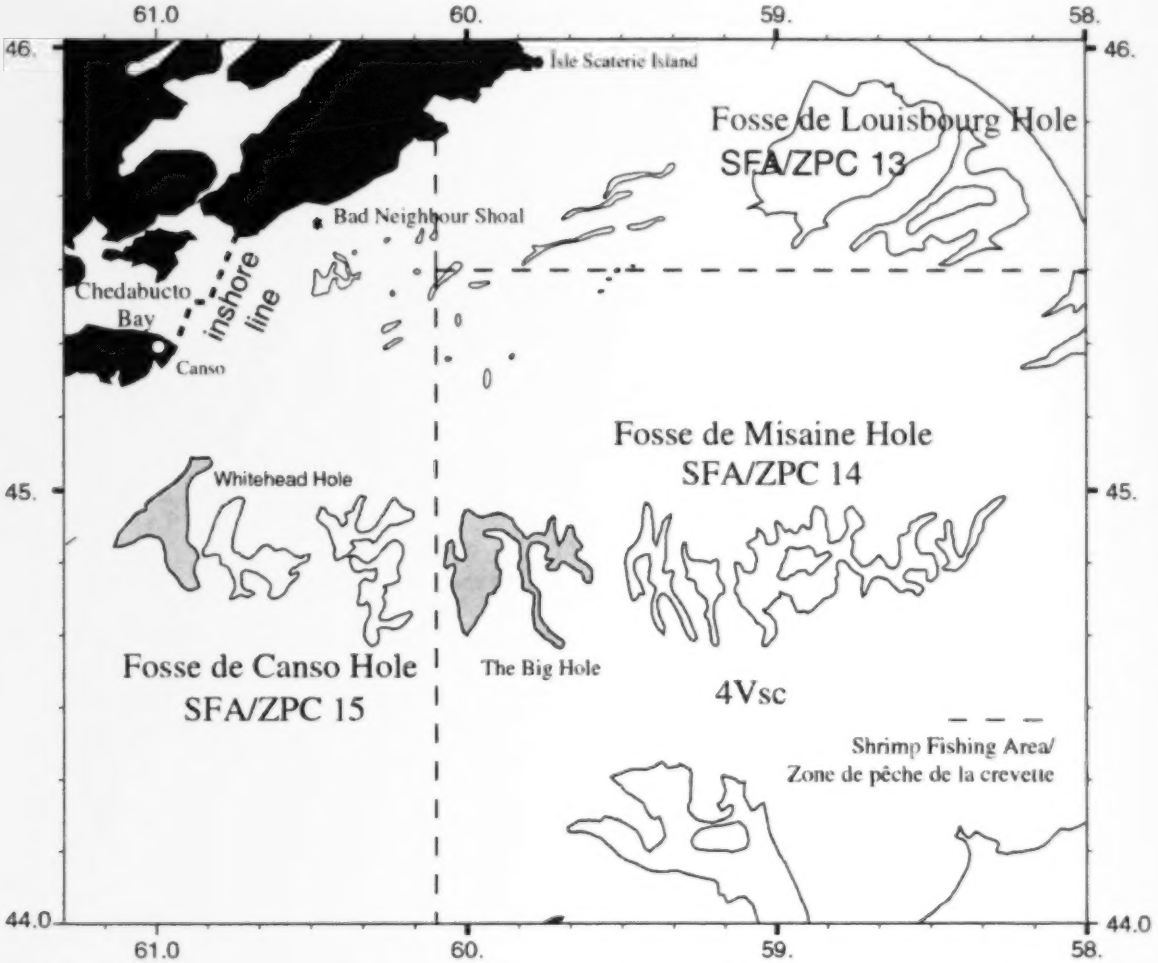

Figure 1. Shrimp Fishing Areas (SFAs) on the Eastern Scotian Shelf. The inshore line prohibits trawlers from fishing inside Chedebucto Bay during the trapping season (fall to spring). Note the distinction between SFAs used to report catches and survey strata defined offshore (Strata 13,14, 15) by the 100 fathom contour (solid lines) and inshore (Stratum 17) by the extent of La Havre clay north of 45°10' and west of 59°20' on surficial geology maps).

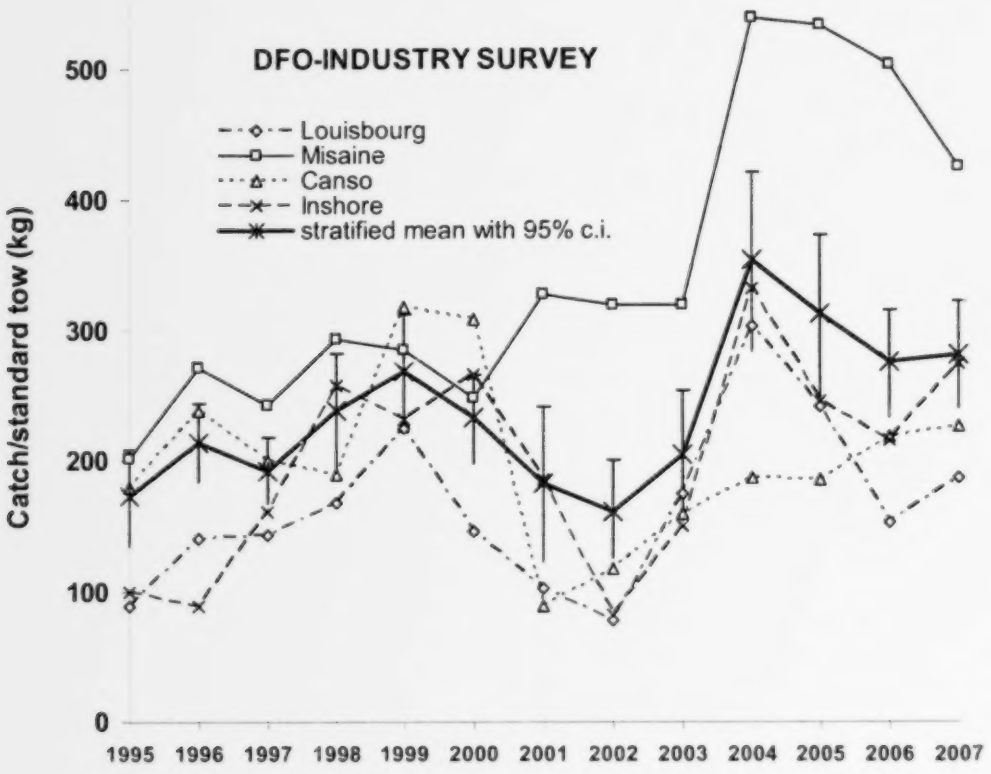

Figure 2. Stratified catch/standard tow for DFO-industry co-operative surveys, 1995-2007 and estimates for the individual strata, which approximately correspond to the main shrimp holes and SFAs. Stratum 13 - Louisbourg Hole and SFA 13; Stratum 14 - Misaine Holes and SFA 14; Stratum 15 - Canso Holes and the offshore part of SFA 15. The Inshore, or Stratum 17, is comprised of inshore parts of SFA 13-15.

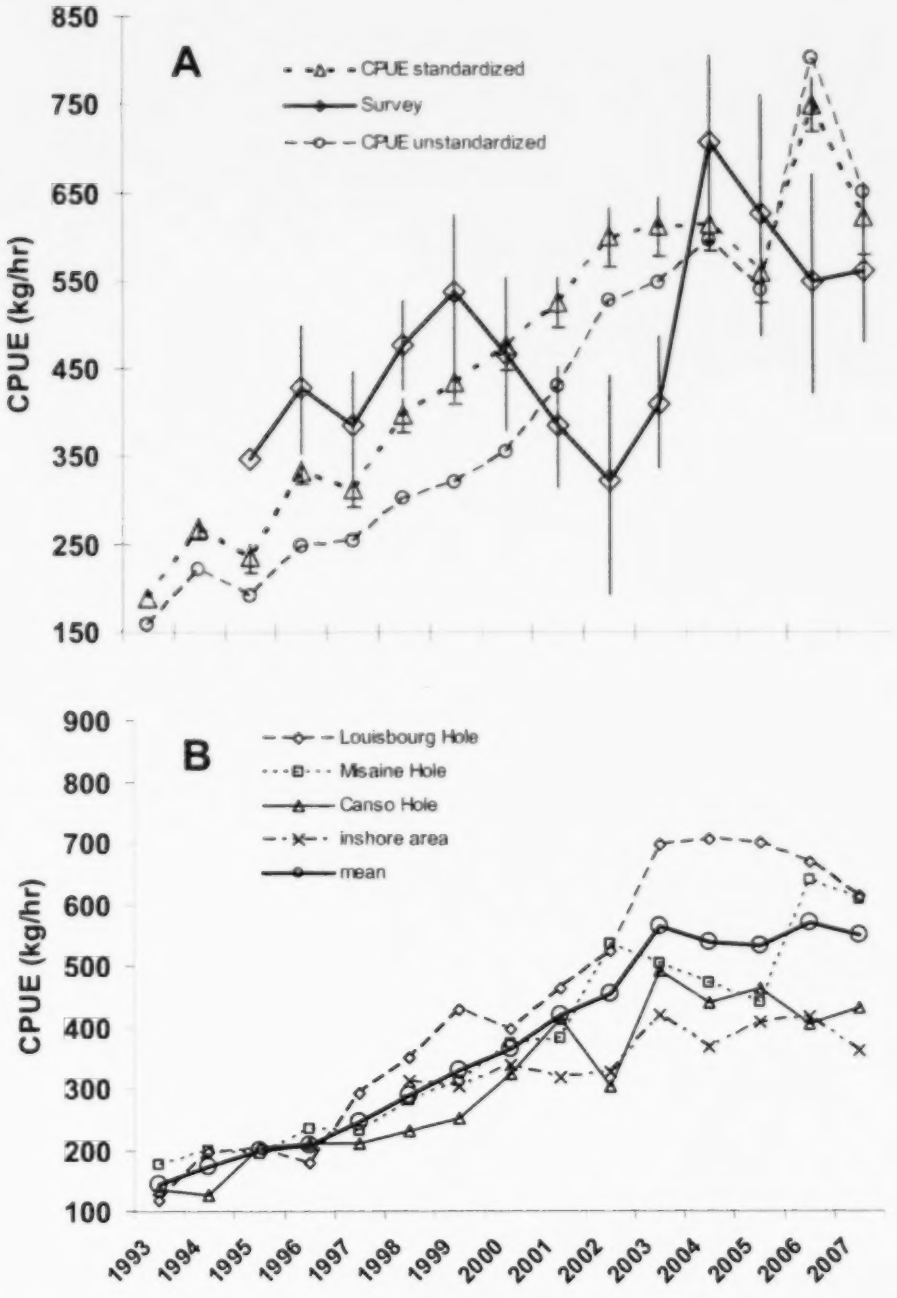

Figure 3. A - Survey stratified estimate (solid line) and standardised CPUE with 95% confidence intervals (dashed line), and B - unstandardised commercial CPUE for each fishing area. Note that SFA15 includes the inshore, but the latter is also shown separately since fishing began there in 1998.

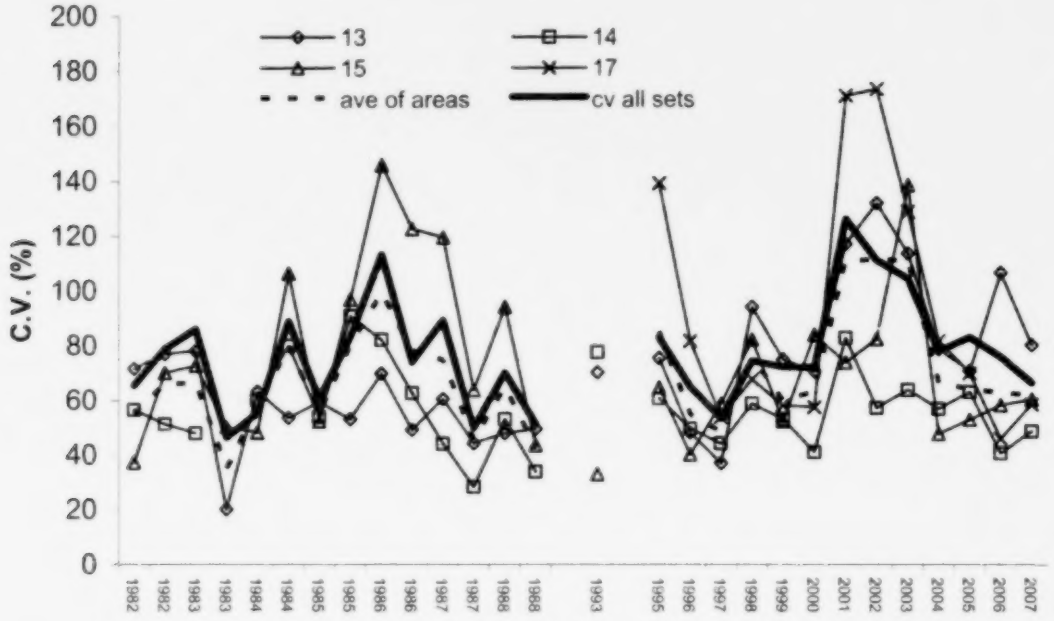

Figure 4. Coefficients of variation (C.V.) for shrimp survey strata 13, 14, 15 and 17. Note that the earlier survey series has two values per year, one for the spring and one for the fall survey.

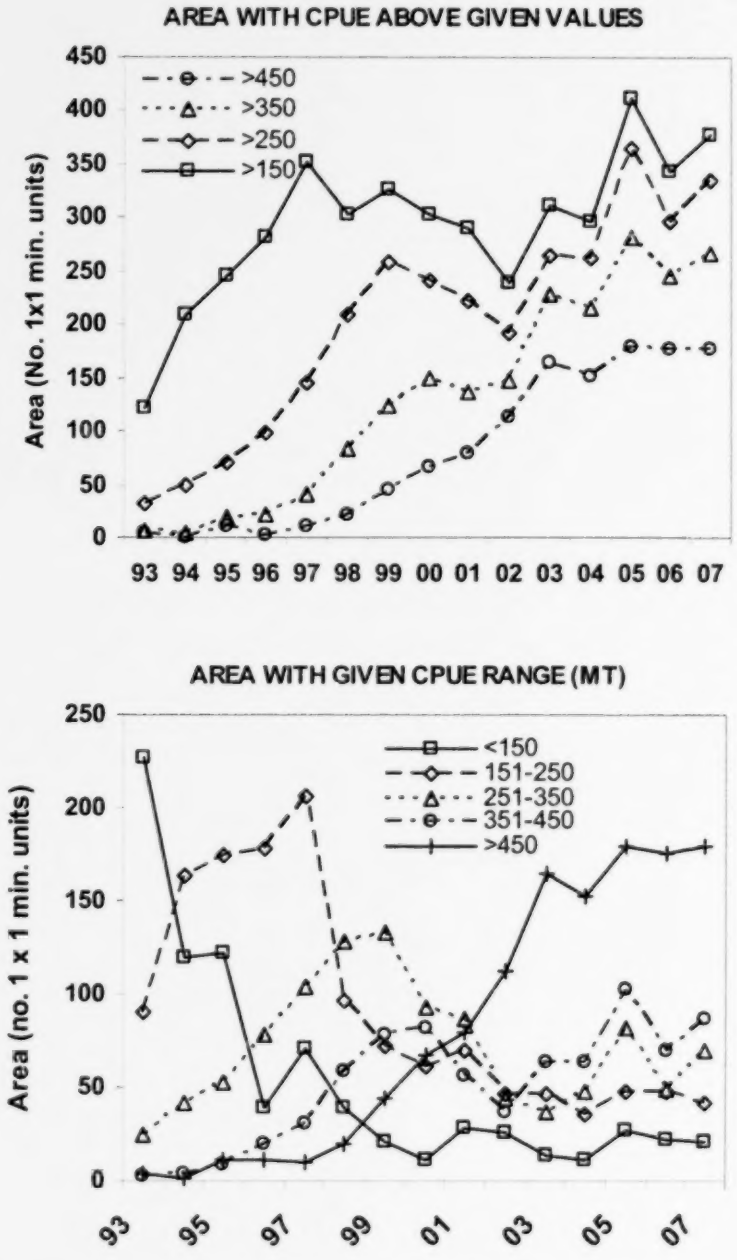

Figure 5. Number of 1 minute square unit areas fished by the shrimp fleet with mean catch rates above (top) and within (bottom) the values or ranges specified in the legend.

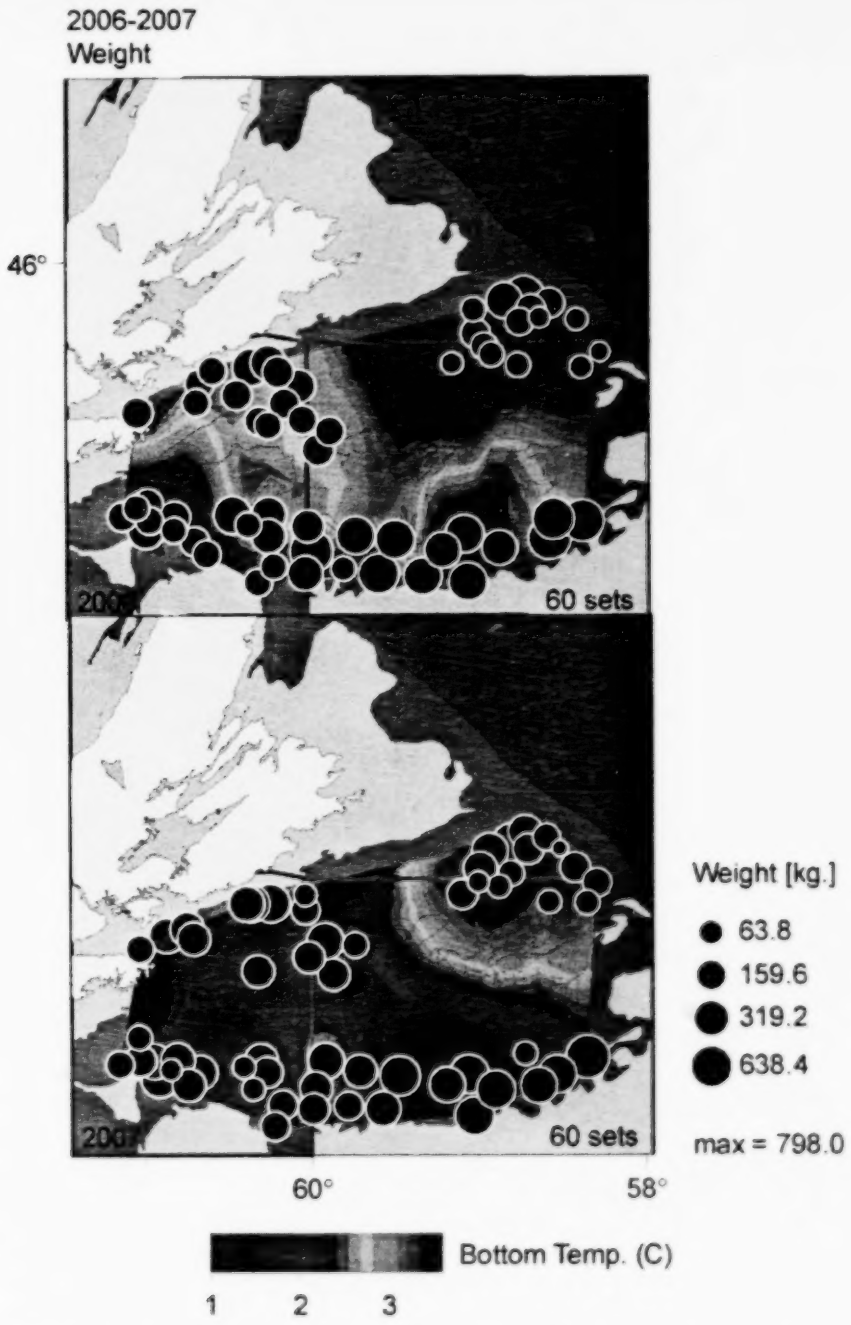

Figure 6. Distribution of catches (kg/standard 30 min tow) and bottom temperatures from DFO-industry surveys 2006-2007. See previous research documents for distributions prior to 2006.

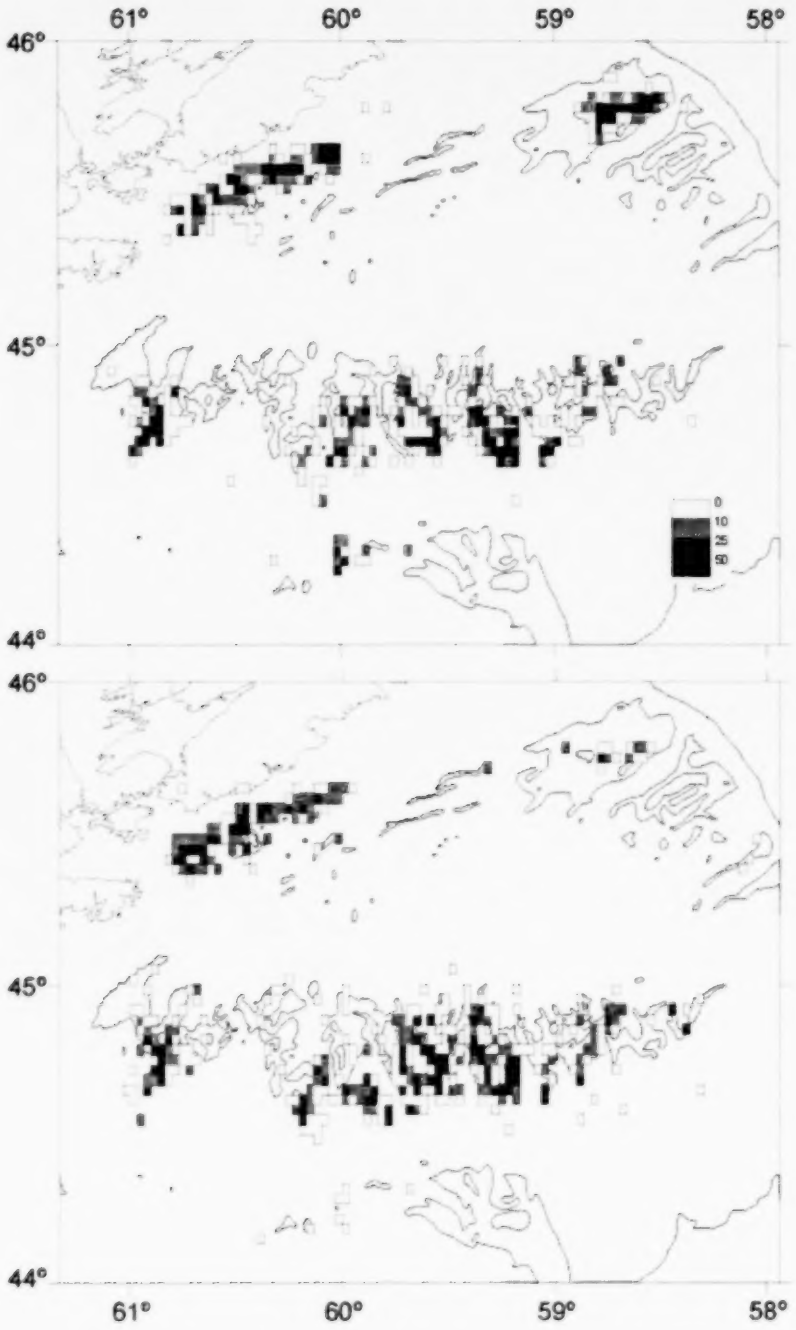

Figure 7. Annual effort by trawlers 2006-2007, cumulative by one minute squares. See previous research documents for effort distribution prior to 2006.

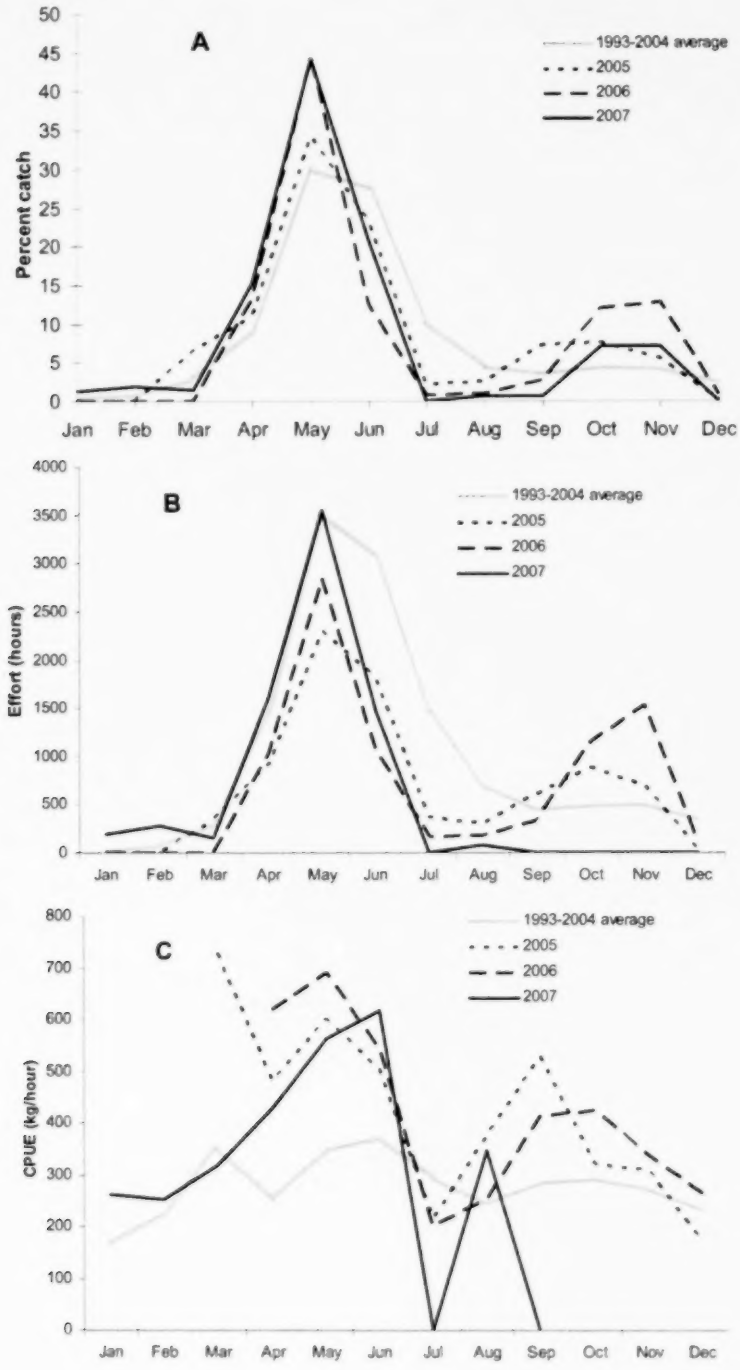

Figure 8. A - catches from the shrimp fishery as a percentage of the total catch, B - average CPUEs and C - total effort, by month.

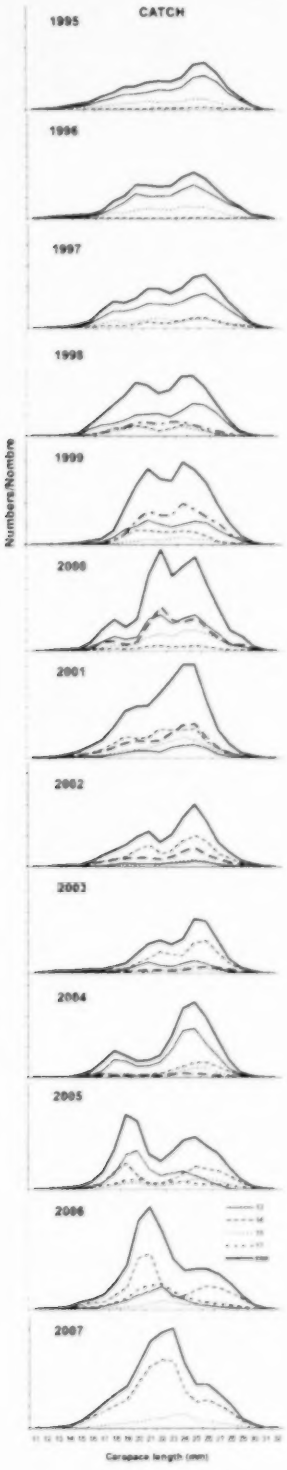

Figure 9. Catch at length from commercial sampling, 1995-2007.

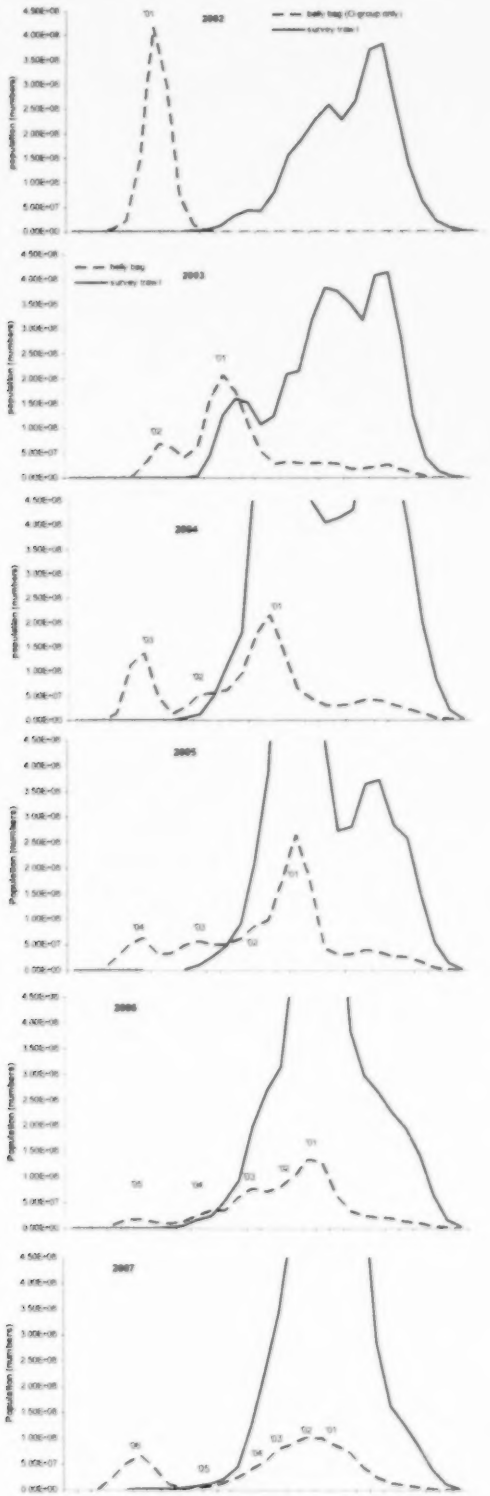

Figure 10. Population estimates from belly bag and main trawl catches for the 2002-2007 survey. Note that the 2002 belly bag estimate was made only for 1-year olds.

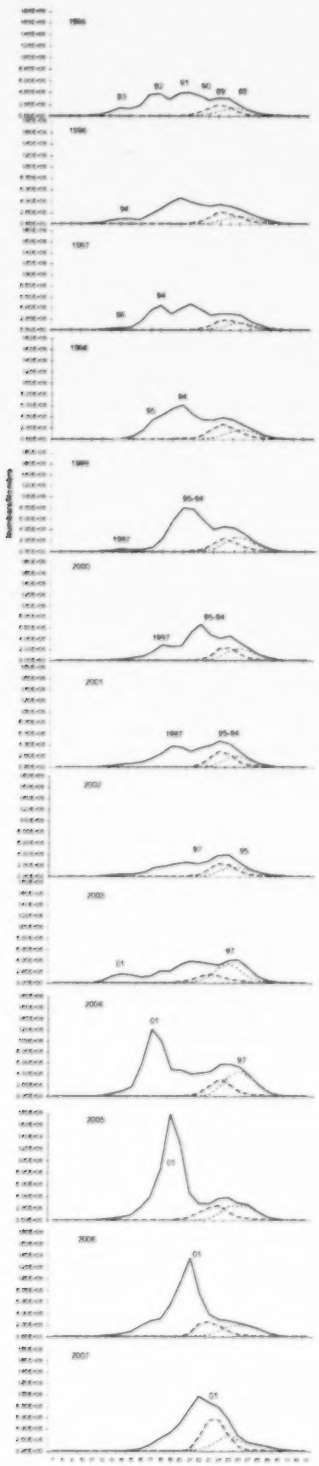

Figure 11. Population estimates at length from DFO-industry surveys 1995-2007. The heavy dotted line in each figure represents transitional and primiparous shrimp, and the stippled line represents multiparous shrimp.

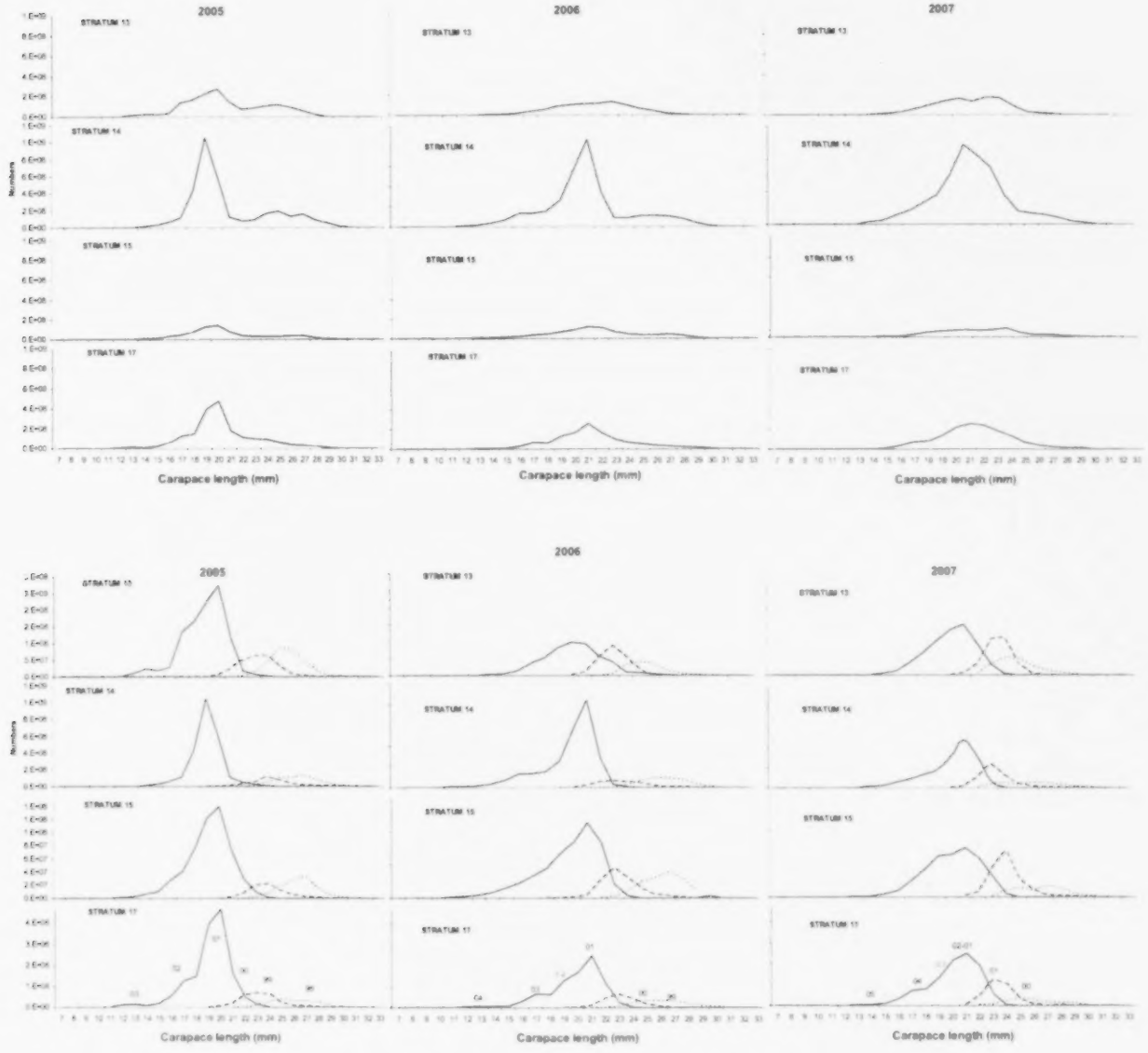

Figure 12. Population at length estimates by Shrimp Fishing Area from the DFO-Industry survey conducted in June, 2005 -2006. Top: all Y-axis scales same, total numbers only; bottom: scales same within SFAs, males (solid line), primiparous (dashed) and multiparous (dotted) females separated.

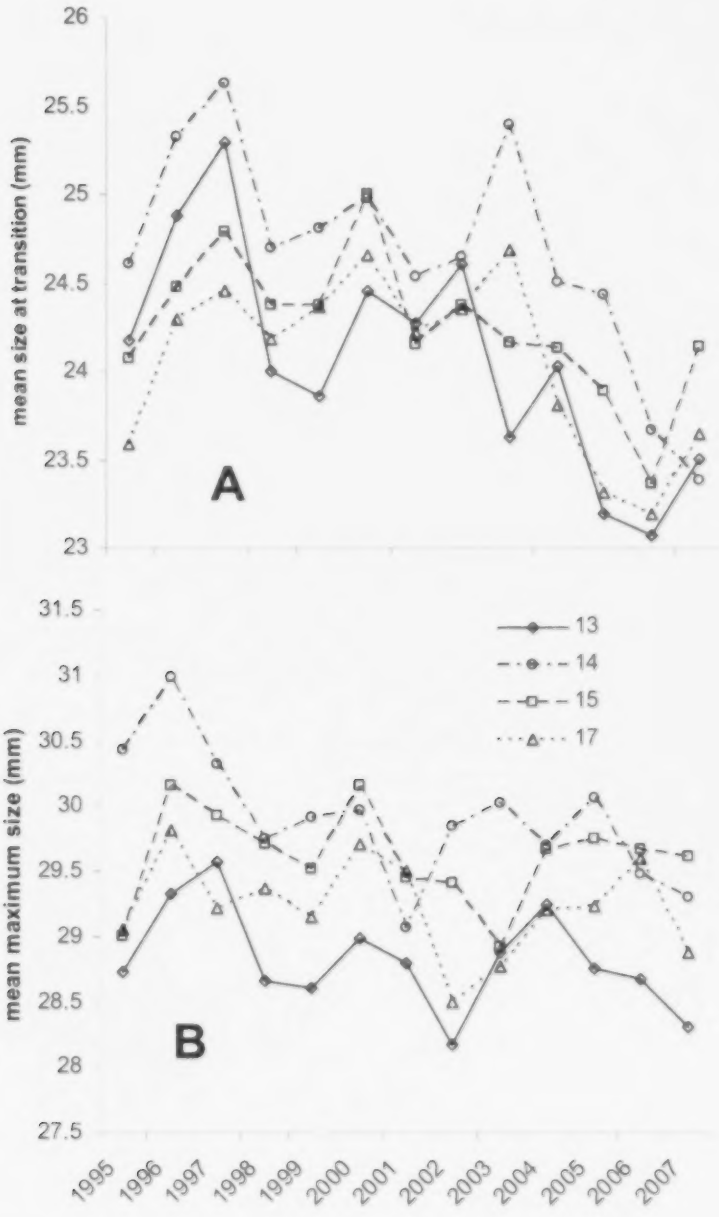

Figure 13. Average size at A - sex transition and B - maximum size by shrimp fishing area for the DFO-industry surveys 1995-2007.

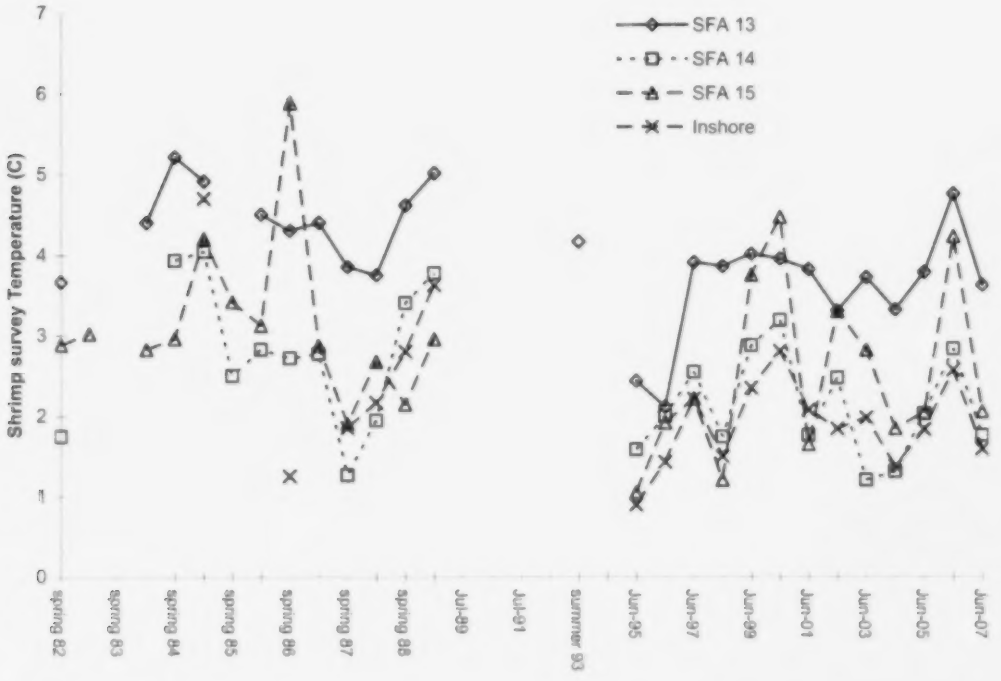

Figure 14. Mean bottom temperatures from shrimp surveys by SFA. Note that both spring and fall values were available from the earlier series (1982-88), but only one survey (June) was conducted annually in the recent series.

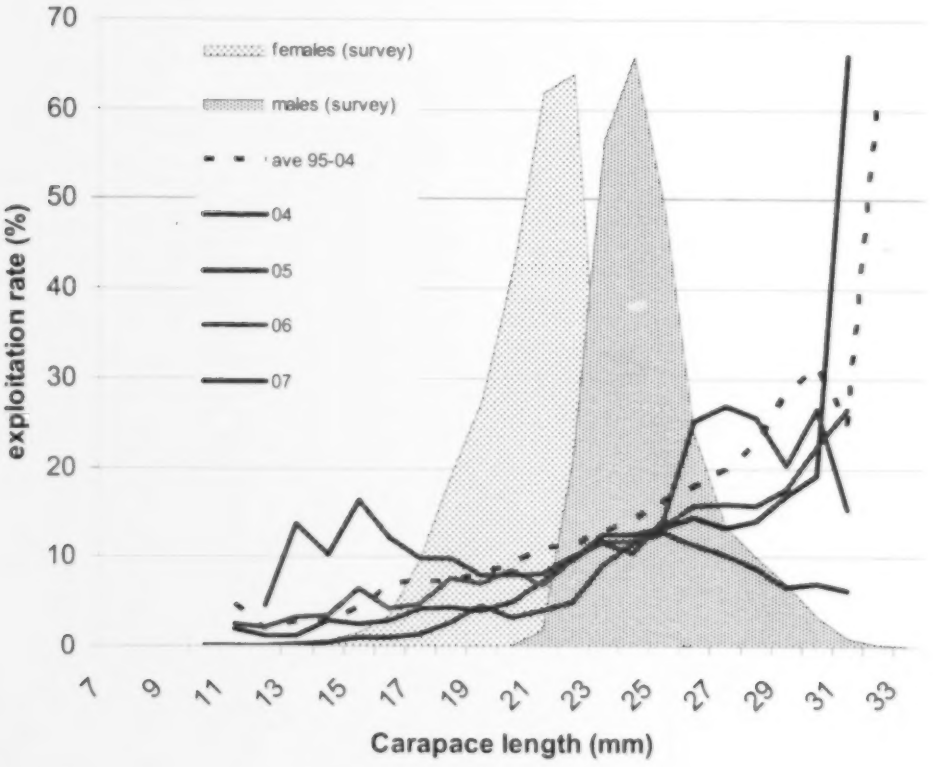

Figure 15. Exploitation at length from commercial sampling and DFO-industry surveys (1995-2007).

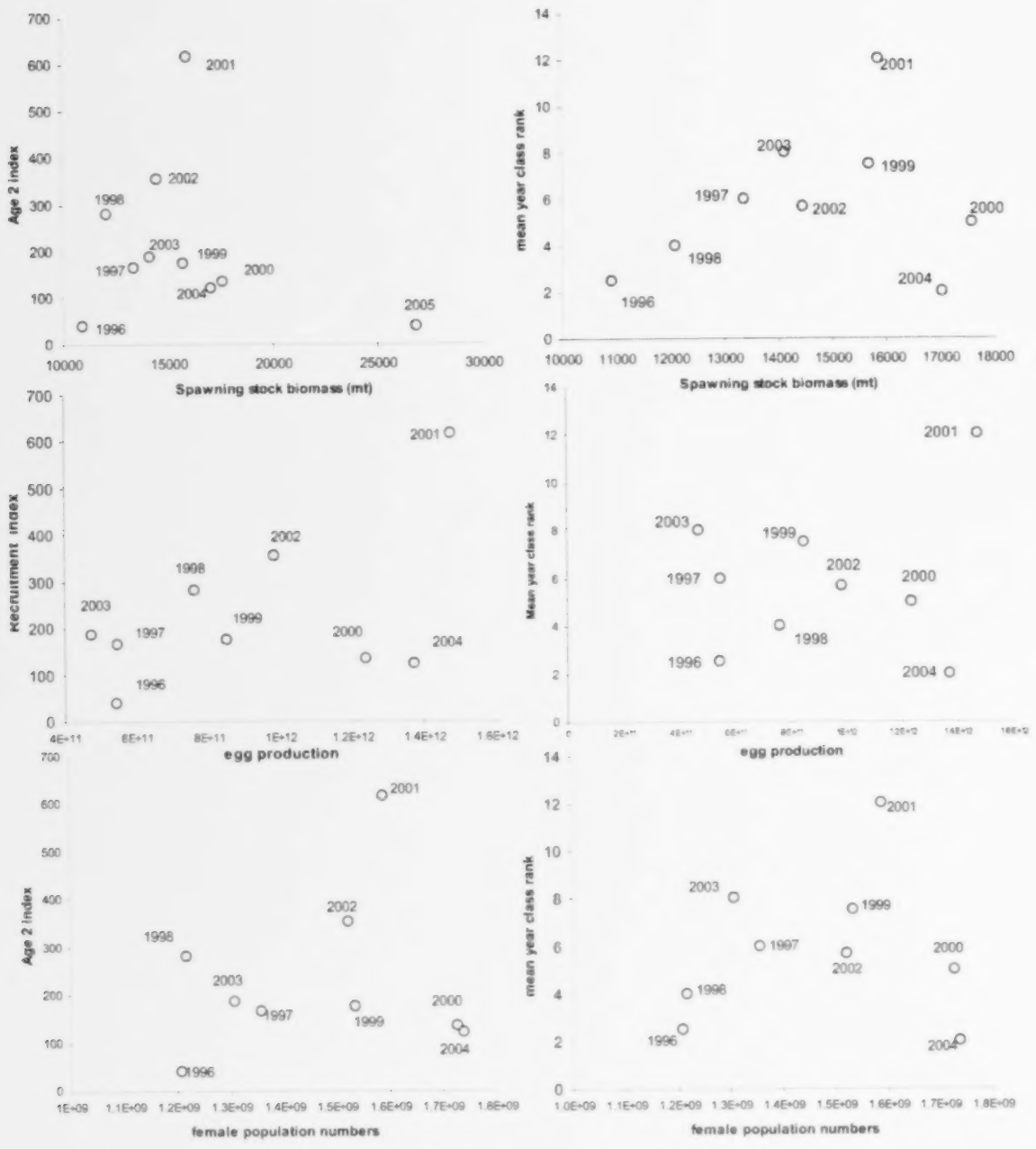

Figure 16. Stock-recruitment relationships between survey indices of spawning stock biomass, egg production and female abundance in year x versus recruitment indices in year x+3. Note that spawning stock indices are from the year previous to the year of hatching since eggs are incubated overwinter from summer-fall to the following spring. Individual year-classes are identified, but note that the outlying 2005 year class is only shown in the first panel.